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The Journal of
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American Volume

FEDERAL SUBSIDIZATION OF MEDICAL EDUCATION *

BY J. S. SPEED, M.D., MEMPHIS, TENNESSEE

It is unnecessary to bring to the attention of this Association the fact that our Nation is facing the most serious crisis or series of crises with which it has ever been confronted. These crises are both international and domestic. International crises we have had before, but they have been solved because we were united in the basic concepts which directed our efforts. If we are to have sound leadership to guide our international policy today, we must revise our national thinking to conform closely to the fundamental principles of a true democracy.

During our lifetime, this country has passed through two world wars; and, from present indications, it may soon be involved in a third. Whether or not there is a third war, we are already engaged in a domestic struggle of conflicting ideologies, an effort by certain elements of our people to reverse the concepts upon which our Constitution was founded, especially the concepts that the freedom of the individual is paramount and that the function of the state is solely to preserve this freedom.

With each national crisis, our Federal Government has assumed more power, leaving the individual with fewer liberties and dulling his consciousness of personal responsibility in shaping the destiny of our country. Freedom and responsibility go hand in hand; we cannot have either without both.

Our greatest danger stems from within ourselves,—a weakening of our moral fiber, a loss of our sense of national obligation, and a loss of our desire and of our courage to struggle with the problems which confront us. We are more and more content to barter our liberty for bondage to a government which promises peace and security without individual effort. The principles of freedom and individual initiative upon which our Nation was founded have been the source of our strength. It would be disastrous if we were to lose that freedom as a result of the very efforts and sacrifices we are making to secure it.

Freedom of education is the foundation upon which all other freedoms are erected, for education shapes the processes of thought. Thinking cannot remain unfettered if its sources and the methods of its teaching are controlled by the Federal Government. Local self-government in education and local responsibility for its support are two of the most priceless of American heritages and are the key to the maintenance of our system of government.

Expansion of the scope of education and the ever-rising costs of education have made the preservation of its independence primarily a question of financial support. It is but natural that the presidents and trustees of our colleges and universities, who are hard pressed to obtain the funds necessary to carry on the activities of their institutions, should look with favor upon the offer of various types of Federal subsidies as a source of relief from their troubles. They should remember, however, that to become dependent upon such subsidies is to lose their independence; it is a well recognized economic principle that the sources of support eventually become the sources of control. A recent decision of the

* Presidential Address presented at the Annual Meeting of The American Orthopaedic Association at White Sulphur Springs, West Virginia, June 22, 1951.

Supreme Court of the United States has established both the legality and the responsibility of the Federal Government to control the activities of subsidized projects.[6]

For the past fifteen years, bills seeking authorization for Federal aid to education have been introduced in Congress. The term "Federal aid to education" is an innocent sounding description of a vicious type of legislation which plans eventually to remove from the people and to allocate to the Federal Government the power to subsidize and to regulate education. We have had ample warning from the experiences of foreign countries and from the Federal subsidization of other phases of our own national economy that the trend toward the Federal subsidization of our school system is one of the most dangerous phases of the expanding authority of the Federal Government.

Is this an irresistible trend, inherent in the social and economic revolution which seems to be engulfing the world today? It certainly is not! If the states, communities, and individuals will take back the powers and responsibilities which our Constitution specifically guarantees to us, and face them realistically, any wrongs or evils now existing can be corrected. One of the most effective means of curtailing the program of the expansion of Federal authority would be the reduction of the sources of Federal income. This can be accomplished by limiting, except in time of war, the power of the Federal Government to levy taxes beyond a fixed maximum.

The passage of the Sixteenth Amendment to the Constitution, in 1913, giving to the Federal Government almost unlimited power to impose taxes, has marked a new era in our social and political philosophy,—an era which has produced, directly or indirectly, profound changes in the American concept of the relation between the individual and the state. The repeal of this amendment may be nearer than we think. Already (as of January 1951), resolutions have been passed by both houses of the legislatures of twenty-two states and by one house in an additional six, petitioning the Congress of the United States to repeal the Sixteenth Amendment and to replace it with another which will limit the power of the Federal Government to tax incomes, gifts, or inheritances in excess of twenty-five per centum.

Thus far, subsidization of education in general has failed, but the struggle has not been abandoned. It has simply been concentrated upon the more localized and vulnerable field of medical education. Since education for the medical profession is more expensive than that for any other career, the problem of meeting its rising costs is more acute. The problem cannot be solved, however, without consideration for the fundamental principles of freedom of thought and independence of administration, which apply to all forms of education.

In 1948, the Federal Security Administrator, Oscar R. Ewing, submitted to President Truman a report on the health of the nation. The report included a plan for certain health goals by the expansion of government medical programs to be supported by compulsory health insurance. Dr. Frank G. Dickinson, Director of the Bureau of Medical Economic Research of the American Medical Association, made an analysis of this report, clearly showing that the conclusions stated therein were not based upon sound economic reasoning, and that they did not represent a true picture of health conditions. Despite the obvious fallacies and mis-statements contained in the Ewing document, it has been used to justify most of the legislation introduced into Congress to subsidize medical education.

The bill to amend the Public Health Service Act and the Vocational Education Act of 1946 (S. 1453), the "Emergency Professional Health Training Act of 1949", which has passed the Senate and is now held in committee by the House, in its "Declaration of Policy" states: (1) There is an emergency shortage of physicians which will increase unless present facilities for training are expanded; (2) The cost of providing adequate professional training is so high that it is impossible for medical schools to operate at present capacity or to expand on a sound financial basis with income derived from private

and state support; (3) Therefore, it shall be the policy of the United States to utilize such of its resources as are necessary to provide adequate numbers of trained physicians.

Actually, there is no emergency shortage of physicians, and in all probability there will not be, with the natural expansion of medical schools under the present system of financing. Our seventy-nine medical schools today have an enrollment of almost 7000 first-year students, of whom approximately 6000 a year will be graduated after 1953 and 1954. Increased state appropriations and other non-federal funds have enabled many schools to increase their enrollments. The University of Tennessee, for example, which is conducted on the quarterly system, will increase its freshman class from 140 to 200 during the next year. Such expansion is healthy, provided quality is not sacrificed for quantity, a change of emphasis which the proposed methods of providing subsidies in the emergency training act would certainly encourage. Medical teaching is highly individualized and cannot be expanded at will on a government mass-production basis. The medical profession has taken the lead in all past improvements in the quality of medical care and is thoroughly competent to continue to do so in the future.

The supply of doctors, or the population-physician ratio, does not entirely determine the supply of medical "service" available. Increasing use of hospitalization and the assistance of trained technical personnel have enabled the doctor to care for more patients,—in other words, to render more medical service.

Vital statistics, such as those on infant mortality, deaths from communicable diseases, and increased life expectancy, all indicate that the Nation is receiving adequate medical care and that this care is improving each year.

Thus, there is no sound economic foundation for the medical calamity predicted in the Ewing report and no emergency necessitating the dangerous legislation proposed to correct it. The report should be regarded, not as a guide for medical planning, but merely as propaganda to be used for furthering socialistic legislation.

The second and third items in the declaration of policy of the Act are subject to criticism on the grounds of both the necessity for and the wisdom of Federal subsidies to education.

The whole problem of the financial needs of the medical schools should be settled by comprehensive surveys to determine the best methods of providing the schools with adequate funds to perform their proper functions without sacrificing their academic freedom. Much informative data relating to the cost of medical education and its possible sources of supply have been accumulated through such surveys as those made by the American Medical Association, the Association of American Medical Colleges, the Surgeon General's Committee on Medical School Grants and Finances, and the National Fund for Medical Education. The conclusions reached from these surveys are available in their published reports.

It is generally agreed, and properly so, that our present system of public education is a public responsibility and should be supported largely by taxation. These taxes should be levied and disbursed and the control of the schools maintained at the state and local-community level. From the success of many states in non-federal financing, it would appear that, with the exception of extensive research programs, our colleges and universities can obtain ample financial support from both state taxation and private donations, if the trustees will make fund-raising an integral part of their administrative program. New York has converted two privately supported medical schools into State institutions. In view of the desirability of maintaining the independence of privately conducted educational institutions, Pennsylvania has perhaps adopted a wiser course in making permanent annual grants to all medical schools in the State without any strings attached. The legislatures of many other states have appropriated sufficient additional funds to finance both the construction and maintenance of state institutions.

There are numerous other sources of income which have not been adequately ex-

plored, nor has the proper approach from the public-relations point of view been made to this vast potential reservoir of funds for medical education. Too much emphasis has been placed upon the needs, the deficiencies, and the pessimistic outlook of our institutions of higher learning, and not enough emphasis has been placed upon the creation of a public consciousness of the indispensable service which colleges and universities are rendering to every phase of American progress and well being.

It is a common mis-statement that the present rate of Federal taxation has dried up the sources of philanthropic giving. A recent survey [5] shows that, during the period from 1922 to 1929, the annual donations of 82,753 taxpayers whose income was over $25,000 amounted to $162,600,000, whereas in 1947, the annual donations of 195,675 taxpayers in this group amounted to $346,001,000. Business and corporation executives clearly recognize the important part medical progress and research contribute to the expansion of American industry. They realize that, in order to share in the benefits of medical progress, industry must aid in the support of medical education and research just as it does in supporting technical education and research.

In 1949, the National Fund for Medical Education was formed by a group of leading business men and university presidents to crystallize this consciousness of responsibility into a pattern of practical support for medical education. The study of the problem made by the National Fund for Medical Education led, in general terms, to the following conclusions:

1. The rising costs of medical education make additional sources of financial support necessary;

2. Grave risks are involved in allowing the solution of this problem to rest entirely with the Federal Government;

3. Medical research and education flourish and complement each other only in an environment which permits wide latitude for original scientific thinking. To the extent that scientific educational environment remains unfettered, scientific research will progress;

4. It is desirable that private support be enlisted in an effort to balance state and Federal support. This will help to preserve academic freedom, leaving the medical schools dependent upon no single source for their revenue.

The foregoing conclusions, reached by a group of practical business men and eminent educators after a careful study of the whole problem of medical education, are sound. They are in accord with the opinions expressed by Dr. Harvey B. Stone and Dr. Donald G. Anderson, representing the American Medical Association in their testimony before the Senate Committee on Labor and Public Welfare in 1949, when the National Health Insurance and Public Health Act were being considered.[7]

It is true that the Federal Government has for years contributed to land-grant colleges and that it has supported medical research. Specific grants for research, however, do not present the same dangers as subsidies, since they do not affect the basic educational planning. While it is theoretically difficult in any given medical school to separate the organization and financing of research from those of basic medical training, practically, it can be accomplished quite accurately. Federal grants-in-aid for medical research, particularly if the research is part of a problem of national scope, are proper sources of income for medical schools.

Organized medicine should also share in the financial responsibility for medical teaching. The tuition of the average medical student pays for less than one third of the cost of training necessary to qualify him for practising his profession. He should be willing to return some part of the income from his practice to the source which provided him such an opportunity. The American Medical Association concurs in this opinion and is contributing to the National Fund for Medical Education.

In summary, a study of the factual data available indicates that adequate funds

for the support of the basic training of our medical schools can be obtained from private sources and from taxation at the community and state level. Federal funds should be limited to grants for specific purposes which do not impinge upon the principle of educational freedom. The amounts of these grants should be such that their withdrawal would not imperil sound financial planning for medical education.

Perhaps I can best convey to you the lesson every American citizen should learn by quoting the convictions of one of our greatest educators, Dr. Nicholas Murray Butler:

"There is not enough money in the United States, even if every dollar of it were expended on education, to produce through federal authority, or through what is naively called cooperation between the Federal Government and the several states, educational results that would be at all comparable with those that have already been reached under the free and natural system that has grown up among us.

"Unless the school is both the work and pride of the community it serves, it is nothing. A school system that grows naturally in response to the needs and ambitions of a hundred thousand different communities will be a better school system than any which can be imposed upon these localities by the aid of grants of public money from the Federal Treasury, accompanied by federal regulations, federal inspections, federal reports, and federal uniformities."

Academic freedom cannot be safeguarded simply by writing into the various health acts clauses presumably limiting the scope of Federal control. The personnel and policies of the Federal Government are constantly changing. Previous commitments are easily altered or revoked by agreement of a majority of Congress, or, in some instances, by the proclamation of a single administrative official. Once the pattern for Federal subsidization of the basic phases of education, whether it be general or medical, has been established, its expansion and control at the Federal level will inevitably follow. It is our duty, as leaders in the field of medical education, to make certain that the freedom and independence of medical education are conserved.

Note: The speaker wishes to acknowledge the kind assistance of Dr. Edward H. Leveroos, Secretary on Medical Education and Hospitals, American Medical Association, Dr. Frank G. Dickinson, American Medical Association, and Dr. Dean Smiley, Association of American Medical Colleges, in the preparation of this address.

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RESTORING FLEXION TO THE PARALYTIC ELBOW *

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

In the hand, which is the important part of the upper extremity, function is dependent upon the ability of the arm to manoeuvre and stabilize the hand for action. Paralysis of the flexors of the elbow in the absence of fusion or bone block of the elbow renders the hand useless. If there is control of the shoulder, flexion of the elbow is of major importance, extension being used only for pushing upward, outward, and downward. The purpose of this paper is to show that there are several useful methods of restoring voluntary flexion to the elbow.

So often various other groups of muscles of the extremity are also paralyzed that we may be at a loss to find a muscle suitable for transfer. Although Steindler's well-known method of transferring the origin of the epicondylar muscles in the forearm to a point two inches up the medial border of the humerus is the recognized procedure, these muscles may not be available for transfer. In solving such a problem, we should first consider, as a basis, which actions are needed and which muscles are available.

There are five methods of muscle transfer, the success of the last three of which is best demonstrated by the moving pictures shown:

1. Steindler's operation (transfer of epicondylar flexors);
2. A modification of Steindler's operation which makes some supination possible;
3. Transfer of the triceps muscle;
4. Transfer of the pectoral muscle;

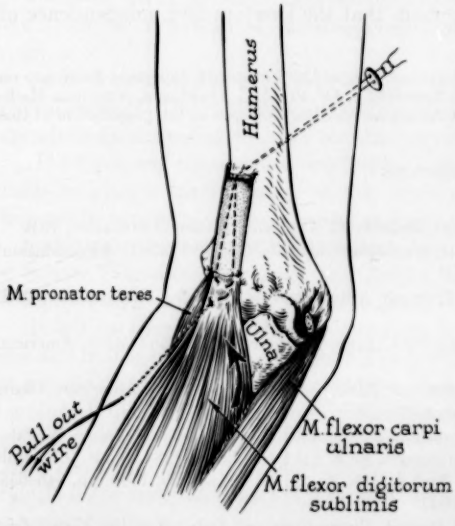

FIG. 1

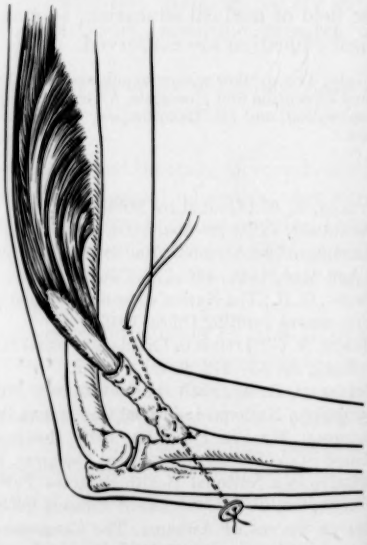

FIG. 2-A

Fig. 1: Modification of Steindler's operation for obtaining a degree of supination in flexion of the elbow.

The origin of the epicondylar flexors in the forearm is fastened to a point two inches up the lateral border of the humerus by means of a free ligamentous graft of fascia lata. This method may be used when the flexor carpi ulnaris is not available to pass around the back of the forearm in order to achieve supination.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1951.

FIG. 2-B

FIG. 2-C

J. McK. The patient's entire right arm and shoulder, with the exception of those muscles supplied by the posterior thoracic nerve, were paralyzed as a result of a belt-and-pulley traction injury on October 8, 1940. Four months later, all the trunks of the brachial plexus, which had been torn apart, were repaired except the posterior thoracic nerve, overcoming gaps up to four inches.

Function returned to the shoulder, including the pectoral, latissimus dorsi, supraspinatus, infraspinatus, subscapularis, teres and triceps muscles, and sensation was restored throughout. Slight activity was restored to the pronator teres and flexor carpi radialis but not to any other muscle below the elbow. Therefore, an amputation was done above the wrist on October 31, 1945.

Fig. 2-A: During the operation the whole triceps muscle was detached from the olecranon, prolonged by a free tendon graft from an extensor tendon of the wrist, and attached to the bicipital tuberosity of the radius with removable stainless-steel wire.

Figs. 2-B and 2-C: The eventual result was the ability to abduct the arm to the horizontal position and to control the shoulder in all directions. The patient could flex his elbow with a pull of 20 pounds to 5 degrees above the right angle (limited by an old injury to the elbow). He was able to use an artificial arm.

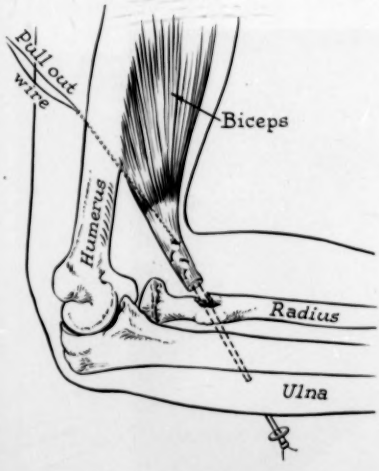

FIG. 3

FIG. 4-A

Fig. 3: Method of attaching biceps tendon or tendon graft to the bicipital tubercle of the radius.

The pronator teres and supinator longus are retracted apart to expose the tubercle, which is then scraped and drilled through while the forearm is in supination. A No. 30 stainless-steel wire, braided into the tendon and made removable by a pull-out wire, is passed through the hole and out through the back of the forearm. The suture pulls the tendon snug to the bone and is fastened to a button on the back of the forearm. The pull-out wire is brought out through the skin and left projecting. After a month, the button is clipped off and the wire suture is withdrawn.

FIG. 4-B

FIG. 4-C

Capt. C. This man, a captain in the army, suffered a gun-shot wound in the brachial plexus. Most of the paralyzed muscles recovered, with the exception of the flexors of the elbow.

Fig. 4-A: On March 3, 1948, a Clark operation was done, transferring a 2½-inch strip of the lower border of the pectoralis major with its blood and nerve supply down through the biceps muscle and the tendon to which it was sutured.

Figs. 4-B and 4-C: The result was free flexion of the elbow up to 130 degrees, although with only moderate strength. In this movement, the patient flexed the pectoral muscle as a whole.

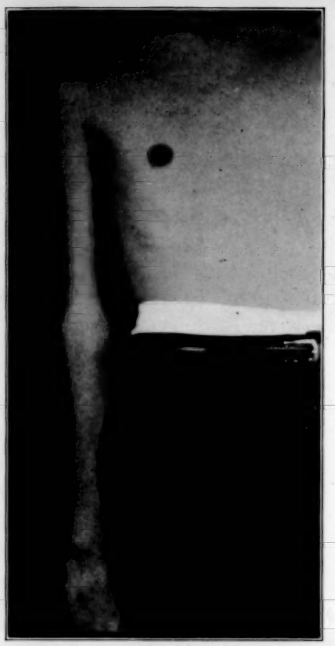

FIG. 5-A

FIG. 5-B

J. B. C. Poliomyelitis left this patient with a useless right upper extremity. He had a flail shoulder and elbow and a partially paralyzed hand. Control to as far as the elbow was given by arthrodesing the shoulder. Arthrodesis of the wrist and transferring several tendons gave activity to the hand, but the hand was still useless as he could not flex his elbow.

Voluntary flexion of the elbow was obtained by transferring, on July 27, 1948, the sternocleidomastoid muscle and prolonging it with a strip of fascia lata, one and one-half inches wide by one foot long, to the bicipital tuberosity of the radius.

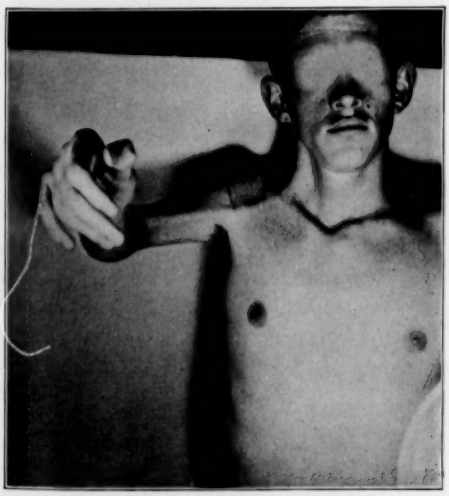

FIG. 5-C

FIG. 5-D

The eventual result was that the practical functioning of the arm and hand was restored to such an extent that the patient's outlook and morale were greatly improved. Through the motion of the arm, he could place and move his hand about so that he could use the hand for light work to a useful degree. He could also flex his elbow freely and with moderate strength.

5. Transfer of the sternocleidomastoid muscle.

Each of these methods, with the exception of Steindler's, which is well known, will be described.

Modification of Steindler's Method (Fig. 1)

This modification tends to lessen the decided pronatory tendency following transfer of the epicondylar muscles to the medial border of the humerus. The origin of these muscles is prolonged by a free graft of fascia lata, so that it will reach to two inches up the lateral instead of the medial border of the humerus. The effect is a moderate but not a complete correction of the pronatory tendency. The standard supplementary procedure for obtaining better supination is to transfer the tendon of the flexor carpi ulnaris, if this muscle is active, around the back of the forearm to the lower end of the radius.

Transfer of Triceps Muscle (Fig. 2-A)

This operation, according to Campbell, is "unsatisfactory", and according to Steindler, "although it has given occasional results, cannot be generally recommended because of anatomic difficulties, and, second, because the loss of function of the triceps is too great a sacrifice". The author, however, has used the method with success. The triceps will not reach to the radial tubercle, but, when it is prolonged by a short fascial or tendon graft, this difficulty is overcome. The whole of the triceps is used, as a muscle should not have two opposing functions. It is far more important to flex than to extend the elbow, and the loss of the triceps as an extensor robs the patient only of the ability to push the arm up or away from the body.

The technical difficulty of attaching a tendon to the bicipital tubercle of the radius is readily overcome by the following method (Fig. 3): The brachioradialis and pronator teres muscles are separated and retracted, and the exposed tubercle is scraped and drilled through. The two ends of a No. 30 stainless-steel wire are braided down through the tendon and are passed by a Keith needle through the drill hole and out the back of the forearm. As the elbow is flexed, these wires are pulled in order to snug the tendon against the roughened tubercle and are fastened on the back of the forearm to a button. After a month, when the tendon has grown to the bone, the button is cut off, and the wire suture is drawn out backward by a loop of pull-out wire provided for that purpose.

Transfer of Part of Pectoralis Major Muscle (Method of Clark) (Fig. 4-A)

In many mammals there is a separate lower part of the pectoral muscle which is attached to the fourth, fifth, and sixth ribs. The corresponding part in man has fused to the main muscle but still retains its separate nerve supply. Clark, in 1946, separated a strip two and one-half inches wide of the lower part of the pectoral muscle from its origin on the ribs and raised this strip of muscle with its nerve and blood supply intact. The muscle was then passed down through the paralyzed biceps and sutured there at about the musculotendinous junction. The same procedure was later followed by other surgeons. The action of the main pectoral muscle is not lost by this method and a fairly strong action of flexion of the elbow results (Fig. 4-C).

Seddon recently reported on sixteen cases. He takes a tail of rectus abdominis sheath with the pectoralis major muscle and identifies the nerve by bipolar electric stimulation. He reports that flexion was strong in seven patients and in all but one of the others there was good movement. Some of his patients learned to contract the two parts of the pectoralis major independently within a period varying from six to twenty-four weeks.

Transfer of Sternocleidomastoid Muscle (Fig. 5-A)

The lower attachment of this muscle is severed, and the muscle is passed subcutaneously down the arm and prolonged by a long free graft of fascia lata. The latter is then

attached by the above method to the bicipital tubercle of the radius by a pull-out suture. This operation provides good voluntary flexion of the elbow.

The second, third, and fifth of these methods are made possible by prolonging the transferred muscle with a free graft of tendon or fascia lata, and by a simple technique for attaching the muscle to the bicipital tubercle of the radius.

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DISCUSSION

DR. C. E. IRWIN, WARM SPRINGS, GEORGIA: To me, as I am sure it was to you, this sternocleidomastoid transfer is most impressive. My experience with flexorplasty at the elbow is limited to Dr. Steindler's original operation and to Dr. Bunnell's modification of that procedure. Therefore, I can discuss this paper only in a general way. I would like to discuss it particularly as it is related to the poliomyelitic patient.

I want to stress one or two points of practical importance which, I think, if not appreciated might prove pitfalls to those of you who have not had experience with this operation. Flexorplasty may take away more independence from the poliomyelitic patient than it will add. Dr. Bunnell stated, if I interpret his statement correctly, that extension was used only for pushing upward and outward. There is one other very important function of extension and that is the ability to push downward. The fact that a patient may be able to support his body weight on the outstretched arm may be the key to that patient's independence.

For instance, the patient who walks on crutches needs full extension of the arm to support his body weight in getting out of a chair. For this action he must go through the following motions: he must push himself backward into an upright position; he must then extend his arms fully; and for a moment he must rest his body weight on one extended arm to reach for his crutches. Once he is on his feet, he again requires full extension of his arms for weight-bearing. The wheel-chair patient also needs extension, for the purpose of shifting his body weight from one position to another. For instance, he uses extension for getting out of his chair onto his bed, or for getting from his chair onto the toilet, *et cetera*.

The most efficient flexorplasties in my experience may have been those in which some residual flexion contracture is evident in the end result. This can be obtained from a Bunnell modification of a Steindler flexorplasty. However, as this would result in more flexion than a weak triceps can stand, I think such a patient's independence would be severely restricted. I am sure Dr. Bunnell has taken this into consideration. I merely want to stress the advisability of not doing a flexorplasty on every patient who lacks flexion of the forearm toward the arm, even though he has available motor power for transfer from one or more sources. A patient who is ambulatory without supportive apparatus, who cannot flex the forearm toward the arm, and who has a motor suitable for transfer is an ideal candidate for flexorplasty. I think this is one of the most useful procedures we have for rehabilitation of the upper extremity.

When I received Dr. Bunnell's abstract, I looked up some muscle values related particularly to fiber length and to excursion. These were interesting to me, and I shall pass them on for what interest they might have for you. The biceps has an average fiber length of 5.1 inches and experimental excursion of 2.5 inches. The pectoralis major has a fiber length of 6 inches and an excursion of 3.4 inches. On that basis it would seem that transferring the pectoralis major to the biceps, particularly with a good base from which it can function, would be an ideal procedure. On the other hand, the triceps has a fiber length of 3.1 inches and excursion of 1.7 inches, both much less than that of the biceps. In addition to the inadvisability of removing the extension of the forearm toward the arm, it would seem that transfer of the triceps would not be as satisfactory.

I would like to describe a different technique for mobilizing a muscle mass for transfer. I believe that in the hands of the occasional operator, this procedure can be performed more safely and with more assurance than those in use at the present time.

An incision about three and one-half inches in length is made, beginning just above the medial epicondyle of the humerus and extending distally toward the radial side. The lateral flap is reflected and the lacertus fibrosus is divided. The median nerve is identified but not disturbed. In the distal end of the incision an internervous plane between the sublimis mass and the mass of the flexor carpi ulnaris profundis is easily identified. By inserting a finger, the operator can carry dissection proximally "with the grain" of the musculature without danger of damaging vital structures. The ulnar nerve and artery are plainly visible beneath the dissecting finger on the profundis mass just under the border of the flexor carpi ulnaris. The median nerve is

(*Continued on page 590*)

BOW ELBOW (CUBITUS VARUS)

BY DON KING, M.D., AND CHARLES SECOR, M.D., SAN FRANCISCO, CALIFORNIA

From the Division of Orthopaedic Surgery, Stanford University School of Medicine, San Francisco

The normal outward deviation of the supinated forearm at the extended elbow is not an anatomical characteristic peculiar to man. This inclination or "carrying angle" appears early in intra-uterine life, is completely developed in the newborn, and, under normal conditions, remains unchanged throughout life.

The astonishing appearance of progressive ulnar paralysis in patients with an abnormal enlargement of the carrying angle (cubitus valgus) long ago directed the attention of surgeons to this curious condition and quickly led them to a full understanding of its genesis and treatment. An incomplete anatomical reduction of the upward, outward, or rotational displacement of a child's fractured lateral humeral condyle may be followed by non-union and a slowing or cessation of growth in the lateral half of the epiphysis. The carrying angle then becomes greatly increased, and eventually the ulnar nerve becomes damaged by stretching over the apex of the angle on the inner surface of the elbow. Moreover, since the head of the radius now articulates against a movable, ununited capitellum, the joint is weak, unstable laterally, and possibly painful.

Supracondylar osteotomy of the humerus (to correct the knock-elbow deformity), anterior transposition of the ulnar nerve (for the neuritis), and, infrequently, bone grafting of the capitellum to the humerus (to improve stability) are the ordinary surgical approaches to the problems presented by cubitus valgus.

These serious and dramatic complications have made cubitus valgus a favorite and fascinating subject for both authors and readers, so that over the years an abundant but somewhat repetitious literature has developed.

FIG. 1

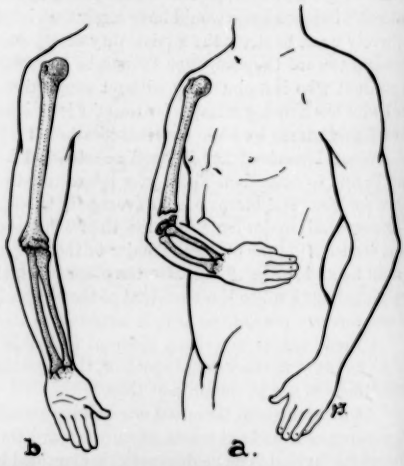


FIG. 2

Fig. 1: The upper extremities of a woman, aged fifty-five years, with cubitus varus of the right elbow as the result of a fracture at the age of five. There is no disturbance of function, but she has always been "sensitive" about its appearance.

Fig. 2: Medial tilting of the distal fragment caused by splinting the arm against the trunk (*a*). This may result in cubitus varus (*b*).

FIG. 3-A

Cubitus varus of the right arm, 18 degrees. Normal carrying angle of the left arm, 15 degrees. Correction necessary, 33 degrees.

FIG. 3-B

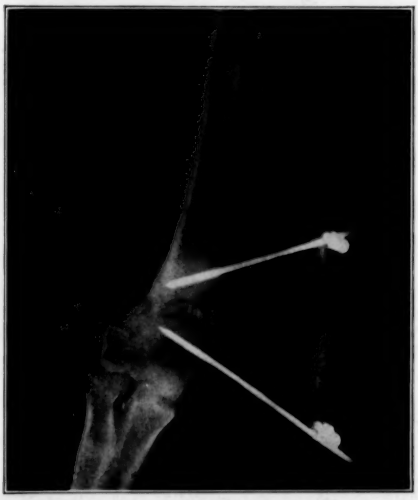


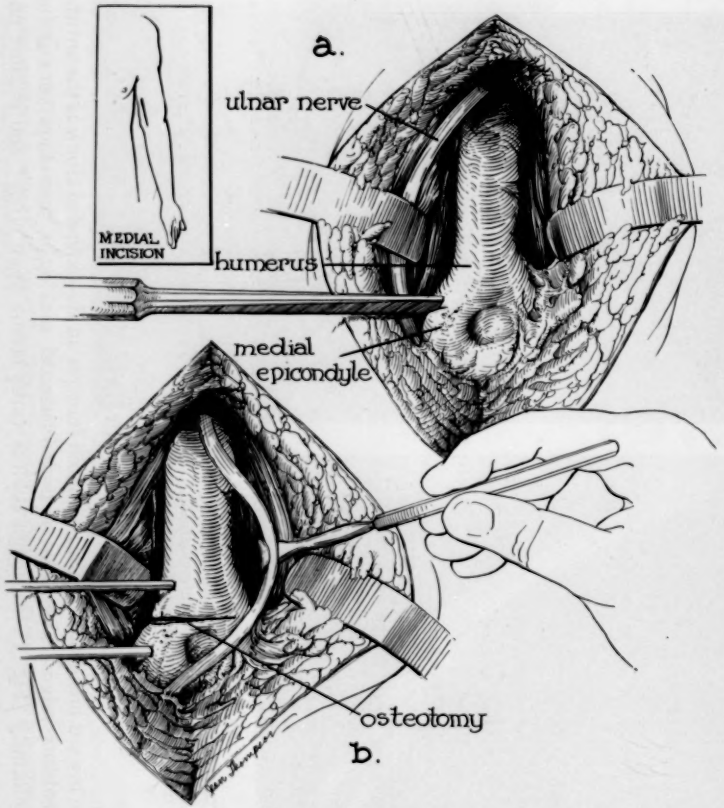
FIG. 3-C

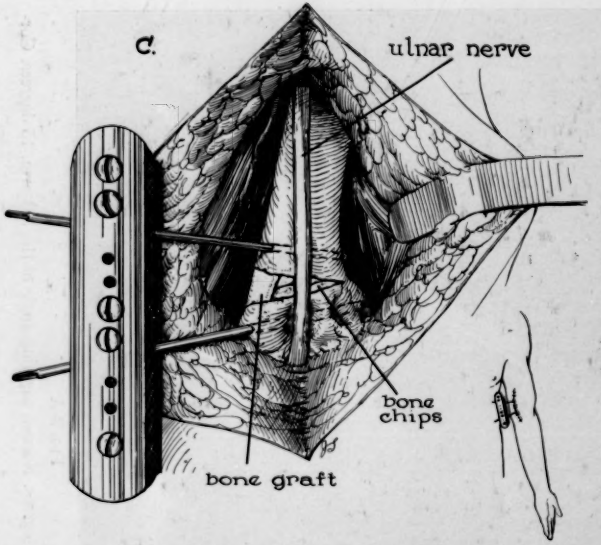
Fig. 3-B: Result one year afterward. Overcorrection about 5 degrees.
Fig. 3-C: A postoperative roentgenogram to illustrate the placing of pins and clamp. The osteotomy is shown held open with bone grafts.

CUBITUS VARUS

The inward inclination of the supinated forearm on the extended elbow is the antithesis of cubitus valgus. The elbow is bowed outward, making a "bow-elbow" or cubitus varus deformity (Fig. 1). Although cubitus varus occurs more often * and is more un-

* Eight to one in our series.





Drawings illustrate the operative procedure. It will be noted (*a*) that the incision begins below the medial epicondyle, that it extends upward directly over the olecranon fossa, and that it continues some further distance along the medial surface of the upper arm. In *b* is shown the insertion of a Steinmann pin into the distal end of the proximal fragment; a second pin is shown inserted into the proximal end of the distal fragment, just above the epiphyseal plate. *c*: A tibial graft, cut to proper length, has been snugly wedged into the mouth of the osteotomy and the remaining "dead space" has been filled with smaller grafts.

FIG. 4

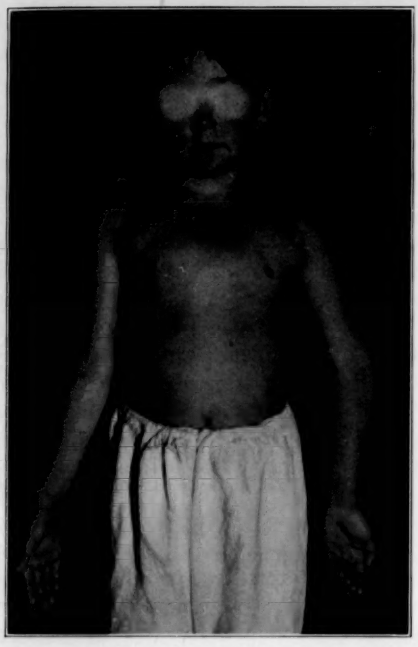


FIG. 5-A

FIG. 5-B

Fig. 5-A: Cubitus varus of the left arm, 1936.
Fig. 5-B: Roentgenogram of the same arm in 1949, thirteen years after the osteotomy.

sightly than cubitus valgus, it has attracted little attention, and few authors have dignified the deformity by writing about it.

Etiology

The sole cause of the deformity in the fifteen patients treated by us was an unreduced medial tilt of the short distal fragment in a supracondylar fracture of the humerus. Three of our patients did not have a doctor at the time of the injury, but carried the broken arm in a sling against the convex surface of the trunk,—a perfectly natural splint, but one with a tendency to adduct the distal fragment and to produce cubitus varus (Fig. 2, *a* and *b*). Observation of several of these patients over a period of years indicated that there is little if any tendency to spontaneous correction of the deformity.

SURGICAL CORRECTION OF CUBITUS VARUS DEFORMITY

Preoperative Roentgenograms

With the patient supine, anteroposterior roentgenograms of the upper extremities are made, the elbow being in 180 degrees of extension and the forearm in complete supination. The degree of deformity, the normal carrying angle, and the amount of correction necessary are thus easily ascertained (Figs. 3-A, 3-B, and 3-C). The osteotomy is sketched on a paper model made from the preliminary roentgenograms, the forearm and the distal fragment are abducted into the corrected position, and the width of the osteotomy opening is measured.

Operation

A tourniquet is applied close to the axilla, and the arm is placed on an arm board. The incision begins about two inches below the medial epicondyle, extends upward di-

rectly over the olecranon fossa, and continues some four to six inches along the medial surface of the upper arm (Fig. 4, *a*). The ulnar nerve is mobilized and retracted forward, the small branches to the flexor carpi ulnaris being preserved. The bone is exposed between the triceps and the medial septum. After the osteotomy, which is done about one-half inch above the epiphyseal plate, has been carried partially across the bone, a Steinmann pin is inserted into the distal end of the proximal fragment; then a second pin is inserted into the proximal end of the distal fragment, just above the epiphyseal plate. These pins must be placed posterior to the ulnar nerve (Fig. 4, *b*).

A Riedel clamp is fastened to the projecting ends of the pins, and the osteotomy is completed. Correction can now be easily and safely obtained without losing control of the distal fragment. It is also possible to move the short fragment around into the corrected position without extending the elbow. This is an important advantage in severe deformities, for the ulnar nerve may be very tight, even though it now lies anterior to the medial epicondyle. A tibial graft, cut to the proper length, is snugly wedged into the mouth of the osteotomy and the remaining "dead space" is filled with smaller grafts (Fig. 4, *c*). At this point, if the elbow can be extended, one can check the correction with an arthrometer. After closure, the Riedel clamp is incorporated in a long arm cast, applied with the elbow in 90 degrees of flexion.

Postoperative Care

Four weeks later, cast, clamp, pins, and stitches are removed; and a light cast is applied and worn for another four weeks. Following its removal, two additional weeks in a sling completes the period of protection. The active exercise of natural use which a normal child will give a painless arm is all that is required for the restoration of movement; but many months are required for this to occur. This must be emphasized to the parents before the operation, and it is well to mention it several times during the eight weeks the arm is in the cast. Otherwise the tendency is to expect a miraculous restoration of function as soon as the cast has been removed.

Results

Fifteen patients with deformities ranging from 20 to 50 degrees have been treated as described, with perfect corrections obtained in twelve. (Figures 5-A and 5-B are illustrative of a typical case.) A perfect correction means a complete restoration of the normal carrying angle. In three, the arm is straight in extension,—that is, there is no carrying angle, nor is there any varus. There was in three patients temporary ulnar paralysis which disappeared completely by the time the cast was removed.

SUMMARY

The normal carrying angle of 10 to 20 degrees is present early in intra-uterine life, does not change during childhood, and remains remarkably constant throughout adult life. An unreduced fracture of the lateral humeral condyle will result in a marked exaggeration of this angle, while an unreduced supracondylar fracture is the common cause of cubitus varus. This latter deformity is unsightly but remarkably quiescent. Fifteen such deformities have been corrected surgically with excellent results, no permanent complications, and no recurrences.

CLUB-FOOT: ITS INCIDENCE, CAUSE, AND TREATMENT

An Anatomical-Physiological Study*†

BY STEELE F. STEWART, M.D., HONOLULU, TERRITORY OF HAWAII

"Error chokes the windows of the mind", wrote Davies about three and a half centuries ago (*The Vanity of Human Learning*).

It is the author's wish to clear three windows in the house of club feet; the wicket-window on the path they come, the casement of their living room, and the postern-window that looks to the street called "Straight".

What is the cause of club-foot? The answer must be sought for in more than one field. We must gather evidence from statistics, from history, and from paleontology and embryology as well as from anatomy.

STATISTICAL EVIDENCE

Heredity

Club-foot appears to be hereditary in some ethnic groups. In Hawaii ethnic origins, for economic and educational reasons, are systematically recorded at birth; all congenital defects must be reported by the accoucheur; there is excellent orthopaedic follow-up of all reported disabilities; and the population is insular and for the most part immobile. These conditions create an unusual opportunity for studying the incidence of congenital defects. The Territorial Board of Health has furnished me with records of congenital deformities as of January 1, 1950, from which Table I has been compiled.

TABLE I

INCIDENCE PER 100,000 OF CONGENITAL DEFORMITIES AMONG NATIVES AND AMONG OTHER ETHNIC GROUPS

Group	Population below Twenty-one in Thousands	Club-Foot	Congenitally Dislocated Hip	Cleft Palate and Hare Lip
Hawaiian	8	290	0	290
Part Hawaiian	66	74	2	49
Caucasian	48	102	12	50
Chinese	17	62	6	111
Filipino	34	53	6	102
Japanese	109	39	21	106
Korean	4	72	0	73
Puerto Rican	7	58	15	0
Other	1	0	0	0
Average		93.7	7	97
Average omitting Hawaiian		65.5	7	69

The considerably greater incidence of club-foot and cleft lip and palate among Hawaiians than among other elements of the population is obvious, and the effect of introducing another ethnic strain into the Hawaiian is likewise clear in all three conditions.

Incidence

Club-foot apparently occurs more frequently in some families than in others. Among

* Read at the Annual Meeting of The American Orthopaedic Association, Virginia Beach, Virginia, May 24, 1950.

† Revised manuscript received August 21, 1950; complete illustrations received March 7, 1951.

FAMILIAL CLUB-FOOT

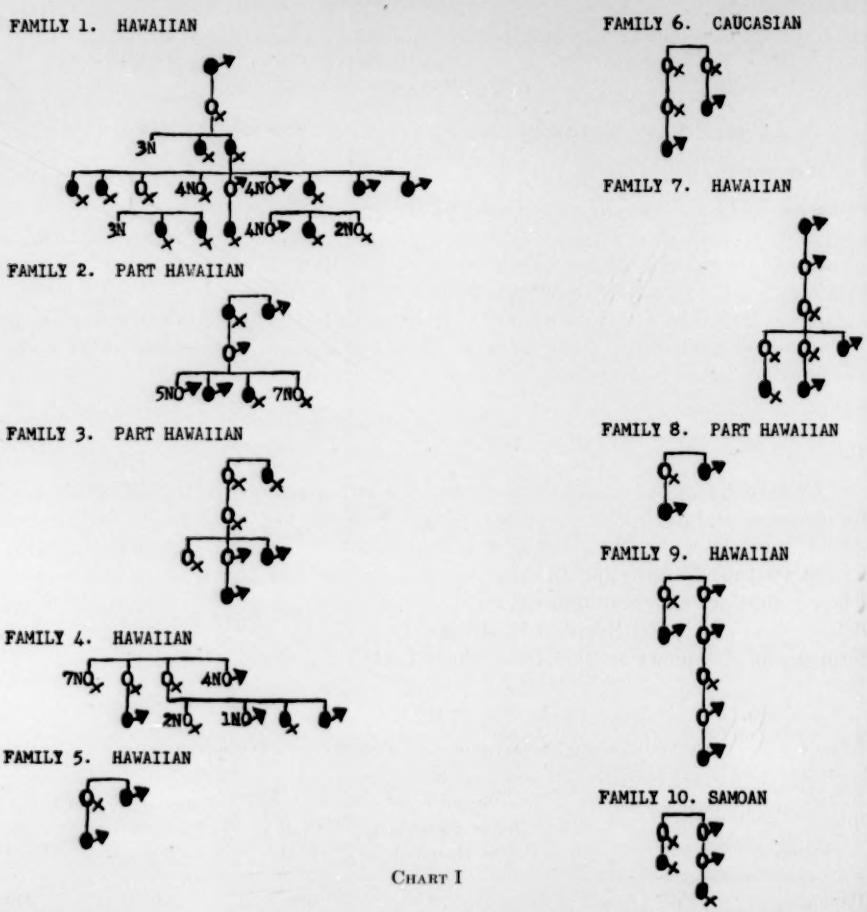


CHART I

240 individuals treated for club-foot at the Honolulu Unit of the Shriners' Hospital between 1924 and 1944, there were ten families giving a history of club-foot in more than one generation (Chart I), and seven families presenting siblings with club-foot occurring (so far as is known) for the first time in their respective families (Chart II). There may have been other cases which were not remembered or not reported. Again we note the Hawaiian predominance.

All recorded series of club-foot show a two-to-one male predominance. In our series 64.5 per cent. of the club feet were in males and 35.5 per cent. in females.

Bilateral and unilateral club-foot was about equally distributed in our series. Jones and Lovett indicate a slight unilateral predominance.

HISTORICAL EVIDENCE

Paleontology

Paleontology offers some interesting sidelights on the problem of club-foot. One of the earliest ground sloths of the Americas, the Hapalops, lived several million years ago in the Miocene era. He was about four feet long and had straight feet. The fourth toe was the longest. In the course of time, this line developed into almost elephantine creatures who walked on the outer side of their feet, as we know from the Folsom footprints. The

CLUB-FOOT AMONG SIBLINGS WITH NO KNOWN CLUB-FOOTED ANCESTORS OR COLLATERALS

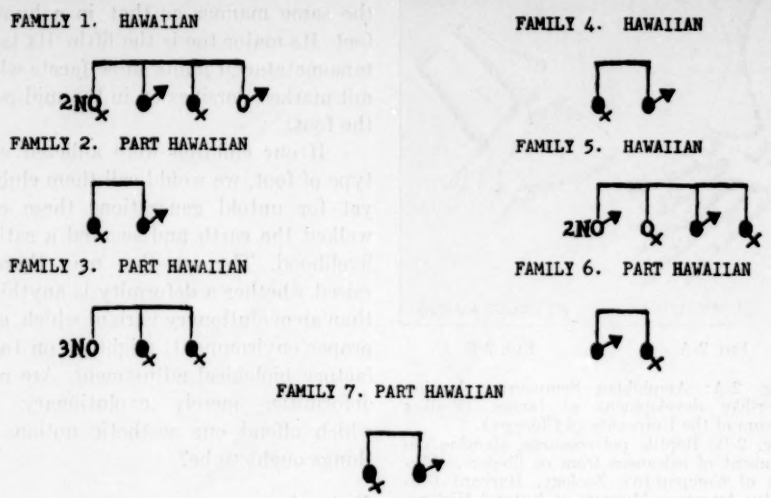


CHART II

first toe had nearly disappeared; the third toe was greatly enlarged; and, in some descendants of this group, only a mighty weight-bearing fifth metatarsal remained of the fifth fin ray. The foot of one specimen of ground sloth examined by the writer showed a peculiar right-angle bony lever in the sole of the foot which was connected to the third metatarsal (Fig. 1-A). Various branches of the family had distinctive foot changes within the adducted and supinated foot. This line probably died out within the last thousand years.

These facts would point toward either the development *de novo* of a dominant characteristic, or the transformation, through unknown causes, of a recessive characteristic into a dominant one,

The specimen in Figure 1-B, an extinct marsupial Diprotodon, comes from Australia; we know nothing of its ancestors. It was nearly as big as an elephant and had several

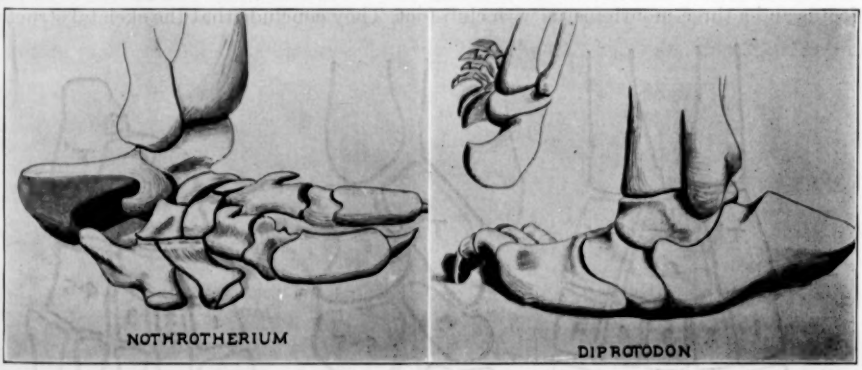


FIG. 1-A FIG. 1-B

Fig. 1-A: Ground sloth Nothrotherium, showing the development of one type of club-foot. (Los Angeles County Museum of Science, History, and Art; American Museum of Natural History, New York; Kensington Museum of Natural History, London.)

Fig. 1-B: Marsupial Diprotodon Australias, showing a very different type of club-foot. (Australian Museum of Natural History, Sidney, Australia; American Museum of Natural History, New York; Kensington Museum of Natural History, London.)

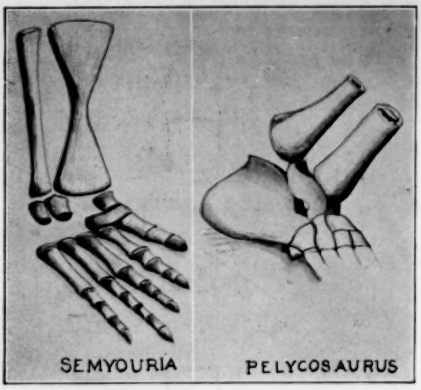


FIG. 2-A FIG. 2-B

Fig. 2-A: Amphibian Semyouria, showing flipper-like development of tarsus. (Walker Museum of the University of Chicago.)

Fig. 2-B: Reptile pelycosaurus, showing development of calcaneus from os fibulare. (Museum of Comparative Zoology, Harvard University; American Museum of Natural History, New York.)

unique skeletal characteristics. In its fourteen-inch hind feet, the calcaneus is twisted in the same manner as that in a human club foot. Its major toe is the fifth. Its tarsal and tarsometatarsal joints show facets which permit marked dorsiflexion in the mid-portion of the foot.

If our children were afflicted with this type of foot, we would call them club-footed; yet for untold generations these creatures walked the earth and secured a satisfactory livelihood. The question may therefore be raised whether a deformity is anything more than an evolutionary variant which, given the proper environment, might go on to a satisfactory biological adjustment. Are not some deformities merely evolutionary variants which offend our aesthetic notions of how things ought to be?

Embryology

Ontogeny and embryology also throw some light on our problem. Originally the vertebrate foot was flipper-like. The bones were arranged as in the specimens shown in Figures 2-A and 2-B. A similar arrangement exists in the 18-millimeter, seven-week-old human embryo.

The major changes in the development of the mammalian foot cluster around the development of the calcaneus. Paleontologically speaking, these changes began in early reptilian days. In the pelycosaurus (sail-lizard) (Fig. 2-B), the fibulare began first to enlarge and then to migrate from beneath the fibula to its ultimate subtalar position. In the human embryo, this process begins after the close of the seventh week and is completed by the tenth week (Figs. 3-A to 3-C). The position of the calcaneus in club-foot would suggest an extension of this migratory process.

Bechtol and Mossman describe two foetus: a probably arthrogrypotic four-month foetus and a three-month foetus with club-foot. They conclude that the skeletal structures

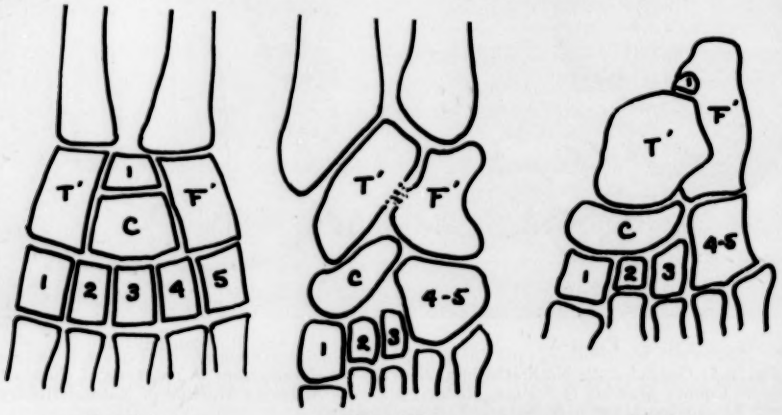


FIG. 3-A
Basic pattern

FIG. 3-B
18-millimeter foetus

FIG. 3-C
Adult

Diagrammatic representation of development of tarsus

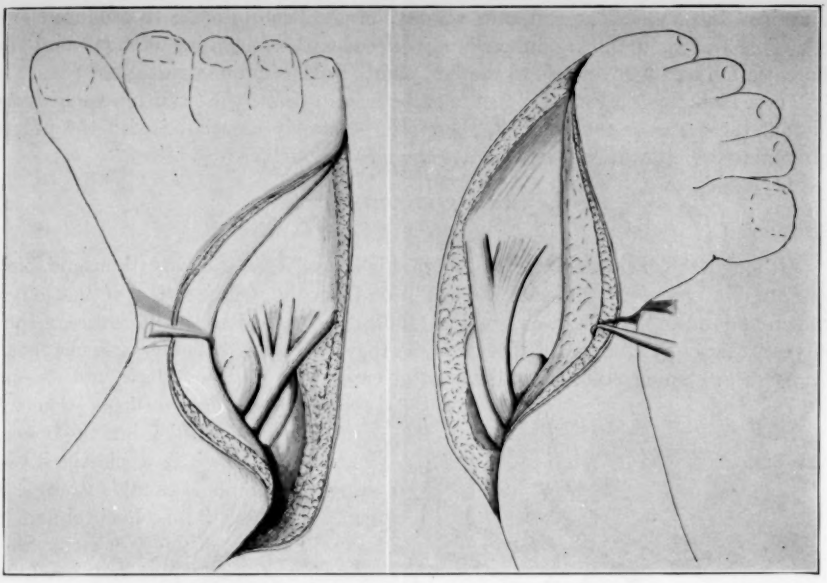


FIG. 4-A FIG. 4-B

Attachments of peronaeus brevis in full-term club-footed foetus.

of the foot apparently develop normally until displaced from the normal position by the abnormal muscular forces resulting from abnormal skeletal muscular development. "The muscle abnormality consists of degenerating muscle fibers which fail to keep pace with skeletal growth, the relative shortening of these muscle fibers being the apparent cause of the deformity." Similar processes have been described by Mau [21].

Experimental Embryology

Comparative experimental embryology also adds to our knowledge. Warkany [35, 36] and others have shown that deficiency of vitamins A or D, riboflavin or insulin deficiencies, and exposure to small doses of radiation in the mother rat will produce foot deformities and other malformations. He has shown further that these deficiencies must occur and be

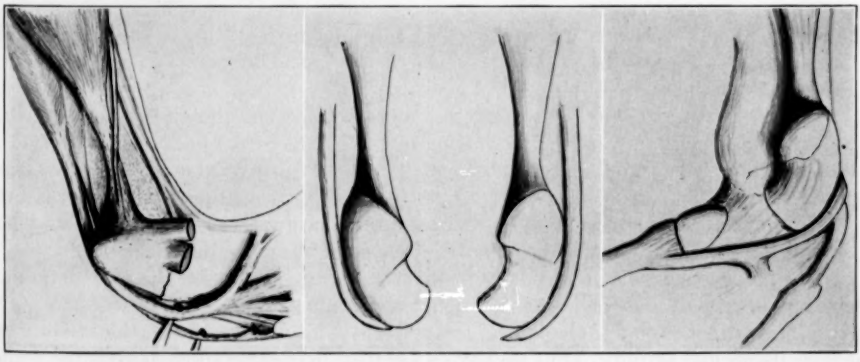


FIG. 5-A FIG. 5-B FIG. 5-C

Attachments of tendo achillis to the os calcis in a full-term club-footed foetus, and attachments of the peronaeus longus.

maintained throughout the first thirteen days of gestation in order to produce these defects. This period in the rat immediately precedes the beginning of bone and muscle differentiation and corresponds to the first eight weeks of human gestation.

These facts suggest that club feet must be formed before the twelfth week of gestation and that the cause or causes must, therefore, be closely associated with the process of embryonic development. Let us examine the feet themselves.

ANATOMICAL EVIDENCE

Literature

Although the incidence of club-foot is high—one case in every thousand births—there are relatively few studies of the condition from the point of view of anatomy. The writer found only thirty-eight anatomical studies of club-foot in the literature of the past 150 years. Six of these must be discarded, as they deal with secondary use changes. The thirty-two remaining stillborn and neonatal cases with club-foot have not been very systematically described, as some writers disregarded everything but the bones, forgetting that bone is a plastic substance subject to environmental stresses. Only eight writers (Adams, Bechtol and Mossman, Funke, Pfrang, Scherb, Shevkunenko, and Weis) give any attention to muscles and then very unequally. Shevkunenko's work, by far the best, is locked in archaic Russian.

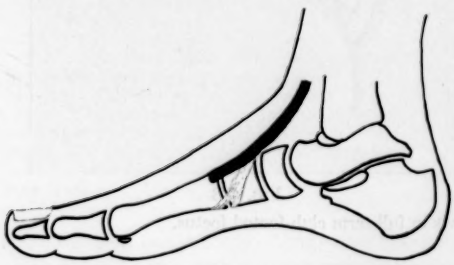


FIG. 6

Abnormal attachment of the tibialis anterior shown in black; normal attachment shaded.

Characteristic Findings

The writer is able to add some facts gained from personal observations to the reports mentioned above. First, he has never seen a corrected or uncorrected congenital club foot which did not have a persistent subcuboidal wedge of fat instead of the normal "lazy-U" plantar cushion. Second, muscle attachments in congenital club-foot, although always diverging from the normal pattern, exhibit different types of deviation in each case; this accounts for the varying degree of severity and the difference in types of club feet encountered in practice. This rather bold statement is based on some twenty operations done by the writer, on the findings in a pair of club feet taken from a stillborn full-term Oriental child with eventration of the abdominal viscera and spina bifida, and on the writings of the eight authors referred to above whose observations agree with those of the writer. Some emphasize one fact or more, but none give all the facts here presented. The drawings in Figures 4-A to 5-B are of the foetal feet. The following is a summary of the author's findings.

The most frequent, most persistent, and most troublesome finding in congenital club-foot of the equinovarus variety is inversion of the heel caused by a malinsertion of the tendo achillis on the medial side of the calcaneus, extending forward on the medial surface. This is a positive deforming force, inverting the heel and twisting the os calcis in its growth.

We come now to a group of muscles whose normal postural force is positive, but whose postural force in club feet may be negative because of insertional peculiarities.

The peronaeus brevis in the normal foot is attached to the base of the fifth metatarsal. Scherb pointed out, and the author has confirmed it many times, that in club-foot its insertion is on the dorsum of the lateral metatarsals. This abnormal insertion diverts and negates its normal activity. Thus we have a negative deforming force, permitting adduction or metatarsus varus (Figs. 4-A and 4-B).

The peronaeus longus is normally inserted into the plantar surface of the internal

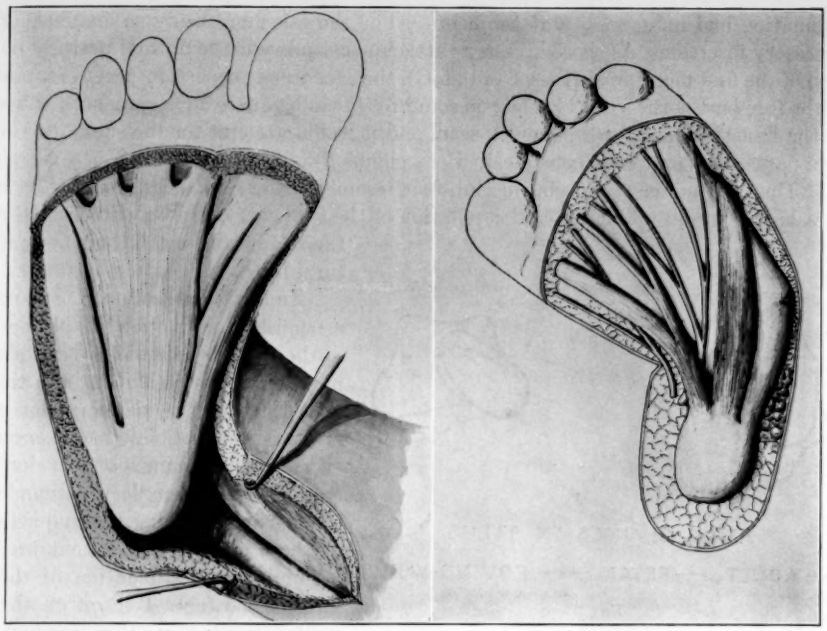


FIG. 7-A
Right

FIG. 7-B
Left

Difference in the plantar tissues of the two feet in full-term foetus with unilateral club-foot.

cuneiform and first metatarsal. In all of the writer's cases save two, there were accessory attachments to the lateral metatarsals; in two bilateral cases, one foot showing slight

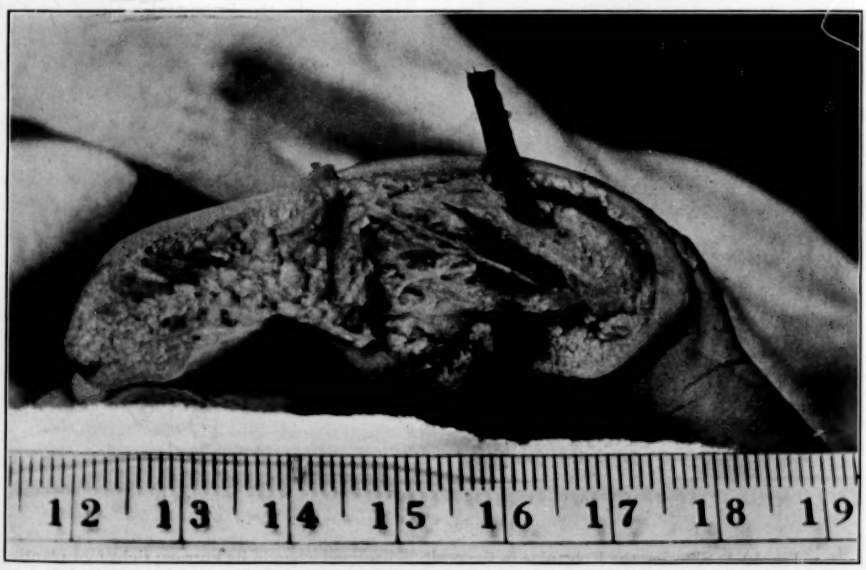


FIG. 8

Dissection of plantar tissues in club-foot, showing their abnormal arrangement and the extension of the lateral portion around the side of the fifth metatarsal.

supination had no accessory attachments, while the other markedly supinated foot had accessory insertions. As these accessory attachments prevent the normal postural depression of the first metatarsal (Figs. 5-A to 5-C), the absence of this action permits supination of the fore part of the foot. This may account for the inadequate development in the region of the first metatarsal so frequently seen, and it would account for the supination of the fore part of the foot erroneously called pes planus.

Thus the peroneal muscles in club-foot resemble extensors and flexors of the metatarsals and permit adduction and supination of the fore part of the foot to occur through their failure to exert their normal postural force.

FIG. 9

In the seven feet operated upon for a persistent adduction of the fore part of the foot, in a case of severe bilateral metatarsus varus, and in both the dissected specimens, an abnormal insertion of the anterior tibial tendon occurred. In these children an accessory dorsal insertion of this muscle was found (Fig. 6). Tension on either the major tendon or the abnormal attachment produced adduction and supination of the fore part of the foot. Tension on the normally inserted portion produced no visible effect. Removal of the abnormal attachment permitted normal tendon action, and, in the first case, the foot became normal postoperatively. In the other cases, it is too early to judge. The tibialis anterior, like the triceps surae, was found to be a positive deforming force.

In the specimens, the posterior tibial tendon was not attached to the plantar surface of the calcaneus and navicular but was lost in a dense mass of undifferentiated tissue in the apex of the plantar arch. This approximates the normal attachment described by Gray.

FIG. 10-A

FIG. 10-B

Epigaulus hatcherii Gidley.

Fig. 10-A: Showing the Epigaulus in the position assumed when in its burrow; right foot plantigrade in advancing; left foot presents entire sole of foot posteriorly in extension. (United States National Museum, Washington, D. C.)

Fig. 10-B: A superior view of the right hind foot and leg, showing the torsion of the tibia amounting to over 90 degrees.

We are familiar with tight plantar bands. In one of the specimens the plantar fascia was split, the larger part passing forward and laterally wrapped around the shaft of the fifth metatarsal to a dorsal attachment (Figs. 7-A, 7-B, and 8). This was a positive deforming factor which could not be anticipated or even located in a living patient; it would form a nearly insurmountable obstacle to correction of a metatarsus varus.

In the club-footed children with the abnormal tibialis anterior, the extensor of the great toe was isolated, but no toe action was obtainable till a forcible pull broke some adhesions. Its force had been combined with that of the abnormal tibialis anterior. In another child, no long extensors of the toes were found in one foot. In two instances, a palpable band, consisting of the abductor hallucis, produced an adduction of the fore part of the foot and abduction of the toe, which was remedied by tendoplasty. It is not surprising that this abnormal muscle pull should cause alterations in the shape of the tarsal bones, either directly or secondarily through pressure.

FIG. 11

Japanese woman and infant; showing mechanism for production of tibial torsion in the human, and end result.

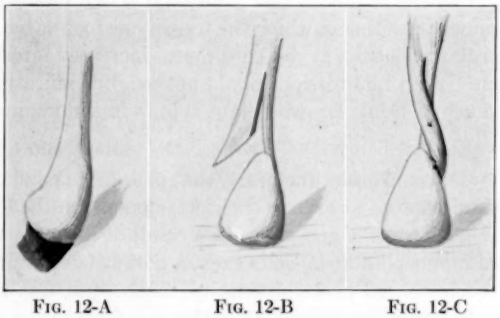


FIG. 12-A FIG. 12-B FIG. 12-C

The switch operation on the tendo achillis.

Most writers on the anatomy of club-foot have directed their attention exclusively to the bones and have concluded that club-foot is due essentially to errors in bone framework, particularly in the talus. It should be remembered that bones have a characteristic growth pattern which brings about changes in their shape with maturity. A similar change occurs normally in the angle of the neck of the talus in postnatal life. When the child is born, the astragalar neck forms an angle of about 36 degrees with the axis of the ankle joint in the horizontal plane. This decreases to 12 degrees in the adult. In neonatal club-foot this angle is more simian and is greater than 36 degrees. Thus, if the talus follows the characteristic pattern of human growth, the adduction element tends to disappear as the child grows older. We are not sure whether or not this occurs in club-foot.

In the same manner, the axis of the talonavicular joint in the newborn lies more horizontally than in adult life. This change would tend to elevate the apex of the tarsometatarsal pyramid, and in club-foot would tend to increase the cavus and decrease the adduction in the growing individual.

Bechtol and Mossman, basing their work on two embryonic specimens (three and four months), conclude, "In neither foetus does the club-foot deformity seem to be a retained early foetal position. The skeletal structures of the foot apparently developed normally until displaced from the normal position by the abnormal muscular forces". Other myogenic or neurogenic causes probably exist.

Another factor, tibial torsion, although it is not a cause of club-foot, tends to perpetuate the deformity by causing a varus bending of the foot at tarsometatarsal joints in walking. It exists in two forms, true tibial torsion and pseudotibial torsion.

True tibial torsion existed in the Epigaulus hatcherii Gidley, a pudgy, horned, burrowing rodent of the Miocene period, which lived in what is now Kansas. Unlike contemporary fossorials, he tucked his feet beneath him and looked like Figure 10-A from the rear as he nosed down his burrow. His position was not dissimilar to that of an infant who sleeps prone with his legs tucked under. Such a child may appear pigeon-toed as he walks, but he is not club-footed, and by the third year his limbs become straight. The Epigaulus, on the other hand, retained this position for life and exhibits the corresponding skeletal changes, as may be seen from a dorsal view of the foot (Fig. 10-B). In each instance the same forces are operative, but club-foot does not develop.

Japanese women never give up the habit of sitting on the medial sides of their feet as they work or engage in social functions (Fig. 11), whereas the males are on their feet most of the day. The result is that the older Japanese women walk just like their own toddlers, whereas the men tend to walk more like the rest of the human race. The lesson is this: In growing bone which is subjected to prolonged torsional strain, torsion will develop in those long bones whose ends are most firmly fixed, while short or movable bones remain normal in shape. In these instances, the fibula remains straight, as do the tarsals and metatarsals, while the tibia becomes involved.

Pseudotorsion of the tibia, apparently a ligamentous affection, is probably more common. It occurs at times in pigeon-toed individuals. It may be distinguished from the true form by the following test. The child is laid on his face and his knees are flexed. The legs assume a position in which the toes of one foot or both point toward the mid-line. Attempts to rotate the tibia at the knee reveal increased internal rotation and limited external rotation. True tibial torsion should not exhibit limitation. This condition can be remedied by the use of Denis Browne night splints in the manner described by Hutter and Scott.

DISCUSSION

It would seem, therefore, that club-foot is due to abnormal differentiation of the individual tendons at or near their attachments in the foot during the period between the fifth to eighth week of gestation. As a result of this process, the triceps surae, the anterior tibial and minor plantar muscles exert a positive deforming force, while the peroneals, deprived of their normal postural activity, cannot function to inhibit the distortion.

It would be difficult to pack these facts into a small amniotic sac; they may be fitted much more congenially into a gene, although avitaminosis, insulin deficiency, and various toxaemias cannot be denied a place as possible causes, especially in isolated club-foot or club-foot occurring in siblings.

These findings, pointing to a genetic basis for club-foot, are in consonance with the best modern thought. The facts naturally lead to an inquiry as to susceptibility to club-foot. Ordinarily, it is said, a club-footed individual occurs once in every thousand births. In Hawaii one was reported for every 1,230 births for the five years ending July 1, 1947.

In a family where one club-footed child has appeared, what is the likelihood of a second? It would appear to be many times greater than in families which showed no club feet; Stern says thirty-six times. This would be true especially in the case of identical twins.

We hope we have cleared the window overlooking the genetic path by which club feet come. We have seen, perhaps for the first time, the mechanism by which club-foot occurs, recurs, and maintains its place in human development. With this added light we may perhaps find and clear the window which overlooks its care.

Prevention

Obviously the occurrence of club-foot in a family should be a warning sign against prospective marriage, and a hazard to be weighed in considering possible children. Clearly

a prospective mother should prepare herself for motherhood by an adequate diet; she should avoid all infections, drugs, and toxaemias during the critical first two months of pregnancy and refuse exposure to any form of radiation, especially of the pelvic area, during that time.

Active Treatment

Given a newborn with club-foot, it is obvious and traditional that the feet should be straightened at the earliest possible moment. The writer's own preference is for use of the Denis Browne splints; others may prefer a cast or strapping.

When the condition has been corrected, but shows a tendency to recur, recurrence and skeletal deformity should be prevented by removing the positive deforming forces and restoring the faulty rectifying synergists to normal activity. The tendo achillis should be exposed through a J-shaped incision and its medial and anterior attachments to the calcaneus should be freed, leaving a small lateral attachment. The tendon should be split longitudinally, so that the free tendinous flap can be transferred to the lateral side of the attached remnant and tacked to the os calcis. A surgeon who adopts this procedure will be surprised at the degree of eversion and dorsiflexion that becomes possible when the medial anterior attachment is freed. The writer has done this more than twenty times, and, to his knowledge, there were only two instances where subsequent lengthening was necessary. The problem of the inverted heel has nearly disappeared.

Second, the surgeon should make an oblique incision in the skin creases over the base of the fifth metatarsal and explore the peronaeus brevis and longus, removing all accessory attachments for these muscles. The writer has done this a number of times with marked improvement of the adduction and supination of the fore part of the foot.

Third, a similar small incision over the base of the first metatarsal should be made and the attachments of the tibialis anterior be examined. Any anomalous attachment to the medial and dorsal surface of this bone should then be freed and the free end fastened in a plantar position. Next, any plantar or abductor bands should be divided. In none of the author's cases were any operative measures on the tibialis posterior found necessary. In older children in whom the condition has been neglected, the problem is primarily one of faulty bone structure.

These procedures, performed under a tourniquet, can easily be accomplished in a short time. The skin is closed with subcuticular stitches. A cast is applied for three weeks and the child is then permitted free use of the foot. This technique has proved very satisfactory. The writer approached the problem a step at a time to judge the effects of each procedure but is now prepared to do all at one sitting.

To some of you this procedure may seem radical; but, in our search for new methods to solve old problems, we must be guided by experience as much as by tradition. As John B. Deaver used to say, "We walk by sight and not by faith".

A final suggestion seems in order. A stillborn club-footed child is born at least once in every 100,000 births. Thirty or more specimens probably appear in the United States annually. Yet we still walk in the dark. It is urged that this Association appoint a committee to gather these specimens, to direct their dissection and record the findings, not only in club-foot, but in congenital dislocation of the hip and other foetal disorders of the extremities, so that we may not be "blind leaders of the blind" who, with our patients, fall into the ditch, but that in the light of true knowledge we may teach and treat intelligently.

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DISCUSSION

DR. WALTER P. BLOUNT, MILWAUKEE, WISCONSIN: The etiology and treatment of club-foot has been discussed since the time of Hippocrates, but it is still a live subject. In his scholarly presentation this morning, Dr. Stewart has presented his résumé of the etiology with beautiful clarity, and he has awakened new interest in the practical significance of anomalous tendon insertions. I have examined his dissections with real appreciation because I dissected three pairs of club feet several years ago. Like Dr. Stewart, I found many interesting anomalies in the tendon attachment. These anomalies, however, were not constant.

In our enthusiasm over the discovery of these specific variations, let us not forget that congenital club-foot is a deformity involving all of the structures below the knee. Brockman has emphasized the significance of thick contracted ligaments on the medial side of the foot, and Moore has pointed out the insufficient myelinization of the nerves. Böhm and others have discussed the developmental deformity of the bones. While none of these conditions is a primary cause to which others are secondary, all of them are evidence of incomplete or arrested development. They appear almost simultaneously in the early weeks of foetal life. In early treatment, we can ignore individual anatomical variations and treat the deformity as a whole.

Dr. Stewart's method should not be regarded as a short cut. As early as possible, the deformity must be corrected by the slow, gentle methods so well described by Kite and others. Even early relapses are best treated by the same method. It is the inveterate recurrent club-foot which is suitable for treatment according to the method described by Dr. Stewart. With a knowledge of abnormal anatomy, we can determine which of the structures are involved, and deal with them surgically. The cause for relapse must be carefully studied.

I have done nine operations which I call "hemi-heel cord transplants" in six patients with an average age of seven years. In these older children, I can recommend a wire pull-out suture to hold the transplanted half of the heel cord in a tunnel in the calcaneus. A J-shaped incision should be placed on the lateral side of the heel cord. The results have been excellent.

In about half of the cases in which a relapse has occurred, the heel cord has not been affected; and the heel has not been in varus. In these I have used other muscle transplantations. After hearing Dr. Stewart's paper, I will look more critically at the tendon attachments. I may only "free them" rather than transplant them.

Please remember that Dr. Stewart said that these conditions are not constant and that each patient must be considered as an individual. Relapses will occur in some patients in spite of all that is done, so that bone operations must be performed. Most of you know the dangers of early bone operations. Let me urge the young men to postpone formal reconstruction operations until the patient is twelve or fourteen years of age. Growth is more likely to produce grotesque distortion in congenital club-foot than in other types of foot deformities.

I should like to thank Dr. Stewart personally for his excellent presentation. I have read the paper over many times and have enjoyed seeing his clinical material. He has made a valuable contribution to our treatment of relapsed club-foot.

DR. M. BECKETT HOWORTH, NEW YORK, N. Y.: Dr. Stewart's work is obviously of great importance, although the question might be raised as to whether these abnormal tendon insertions are primary or secondary migrations.

Dr. Stewart has suggested that this work be continued with whatever specimens become available. May I suggest a parallel line of investigation, because when these specimens are dissected there will not be very many of them, and they will not come very fast. Muscle volume may be just as important as tendon insertion, for three reasons: (1) In poliomyelitis, where there is no change in tendon insertion, deformity is produced by changes in actual and relative muscle volume, which is also a change in muscle power; (2) in unilateral club-foot there is, from the beginning, a distinct difference in the volume of the two leg muscles, which suggests also the possibility of a relation between muscle power and the deformity; (3) in a recent report before the American Association of Physical Anthropology, Dr. Sherwood Washburn reported some very careful studies of muscle volume in monkeys. The muscles of the face were accurately weighed, and a close mathematical ratio between muscle volume and development of the bones of the face, particularly the jaw, was found. This was a very scientific and accurate study; the correlation seemed to be of great significance, and it was contrary to previous anthropological ideas on this subject. If in the future, when specimens of club-foot are studied, we consider not only tendon insertion but also muscle volume, we might gain additional information of value.

DR. JOHN ROYAL MOORE, PHILADELPHIA, PENNSYLVANIA: Dr. Stewart has presented a very beautiful paper; and, if his concepts are correct, I feel he has added considerably to our knowledge of congenital club-foot. It is not quite clear to me whether he thinks that all cases of congenital club-foot have the anomalies which he described. Does he believe that all the club feet we see have the variations in tendon insertions or does he reserve the diagnosis of abnormal tendon insertion for only those which do not respond to conserva-

tive treatment? Brilliant results have been obtained with the Denis Browne splint and from the Hoke plaster-wedging method in the face of such almost insurmountable obstacles as he has described.

DR. STEELE STEWART (closing): I haven't settled the problem of club-foot; I have only pointed up a few facts. Dr. Moore's first question, pertaining to the proportions of primary and secondary congenital type of club-foot, I am unable to answer. I think the point is probably academic. His second point concerns mild cases of club foot. I have described some variations in the degree of deformity; there are probably other elements which I have failed to describe. I have tried to throw into relief the treatment of recurring club-foot. Personally, I would embark on surgical treatment at a very early age, because the earlier it is done, the less secondary bone deformity will magnify the problem and hinder treatment.

Peronaeus tertius defects have not been recognized. Garceau's transplantation of the tibialis anterior to take the place of a peronaeus tertius I think is probably unnecessary. The resection of this tendon seems to produce the same result.

Dr. Howorth's suggestion of measuring muscle volume is interesting, but, in the case of bilateral club-foot, it would be very difficult to establish a norm.

I thank the discussors of my paper, and all of you for your close attention.

DISCUSSION

RESTORING FLEXION TO THE PARALYTIC ELBOW

(*Continued from page 571*)

safely tucked away in its sheath on the under surface of the sublimis mass. By blunt and sharp dissection a muscle mass, consisting of the sublimi, the flexor carpi radialis, the palmaris longus, and the superficial head of the pronator teres, can be mobilized. The only sharp dissection necessary is to free the sublimis from the intermuscular septum between it and the flexor carpi ulnaris and to divide the aponeurotic origin of the muscle mass from the medial pillar of the "tunnel" to the medial epicondyle. It is not necessary to mobilize either the median or the ulnar nerve.

DR. ARTHUR STEINDLER, IOWA CITY, IOWA: Dr. Bunnell's stimulating paper deals with a situation which differs from the usual reconstruction procedure in that the material available for reconstructive purposes is not of normal functional validity. One has to be satisfied to use for substitution muscles which may have no more than 75 per cent. or even 50 per cent. of normal function. The reconstruction of the paralytic elbow is one such situation.

We know, however, that in the case of paralysis of all three flexors of the elbow, the biceps, brachialis, and brachioradialis, the muscle power of the wrist and finger flexors is sufficient to lift the forearm against gravity if their lever arm is enlarged by as much transposition as the motor branches will permit.

This flexor power naturally becomes more effective as the arm is elevated to the horizontal by arthrodesis of the shoulder joint. In fact, I have found many times that a perfectly useful upper extremity could be established, provided that the trapezius, serratus, and the wrist and finger flexors remain available.

So far as pronation is concerned, we try to prevent or correct any such tendency before operation, but as Dr. Bunnell does, we have for years used the method of transposing the flexor carpi ulnaris along the dorsal surface of the forearm and inserting it close to the radial tubercle.

I am very interested in what Dr. Bunnell says about the transposition of the triceps and fully agree that transposing one half of the muscles is useless. No muscle can be educated to become its own antagonist.

Unfortunately, I have had no experience with either the transference of the pectoralis major or the sternocleidomastoid to the biceps by means of fascial lengthening. These difficult procedures require the ingenuity and the masterly technique of Dr. Bunnell. They really seem to be the solution in those cases in which no forearm flexors are available and which, otherwise, would have to be relegated to the arthrodesis of the elbow joint.

I consider it a privilege to be permitted to discuss Dr. Bunnell's most interesting paper.

DR. STERLING BUNNELL (closing): I wish to thank the two discussors for their kind words and I am particularly glad that Dr. Irwin brought out the fact that the triceps is so necessary for raising the body from the chair or from other positions. This applies, of course, to the patient with bilateral involvement. For the patient with unilateral involvement, flexion of the elbow is more important than triceps action.

TREATMENT IN LEGG-PERTHES DISEASE

BY HERBERT E. PEDERSEN, M.D., AND H. R. McCARROLL, M.D., ST. LOUIS, MISSOURI

From the Shriners' Hospital for Crippled Children and the Department of Surgery, Washington University School of Medicine, St. Louis

For years Legg-Perthes disease has represented one of the common problems in clinics for crippled children. In spite of prolonged and extensive study, however, no uniformly accepted method of treatment has been established. It has at times been considered to be a self-limited disease the course of which follows a predetermined pattern regardless of the treatment used. In 1934 Danforth first made a plea for prolonged non-weight-bearing in an attempt to prevent deformity. In 1936 Eyre-Brook compared the results in twenty-two cases treated by bed rest and traction with those in nineteen patients treated by other non-weight-bearing methods. Further progress in this direction was contributed in 1940 by Gill, who presented the results of treatment by bed rest and skin traction in twenty patients. Both Eyre-Brook and Gill claimed that, with this form of therapy, the result in every case should be an essentially normal acetabulum, normal femoral head, and normal femoral neck, provided treatment is started before deformity exists.

At the time of Gill's report, the usual treatment of Legg-Perthes disease at the St. Louis Unit of the Shriners' Hospital for Crippled Children consisted in the use of crutches with the addition of a lift on the shoe on the contralateral foot. It was recognized that such treatment gave excellent results in some instances, but in many cases there was progressive deformity during the treatment period. It was felt, therefore, that continuous bed rest and skin traction should be given a trial, to determine whether the end results would justify a prolonged period of hospitalization. Since that time twelve patients (fifteen hips) have been treated by this method, and the follow-up period has been sufficiently long to permit evaluation of end results. A total of sixty-six children in whom end results have been determined have been treated in this Clinic during the ten-year period 1940 through 1949. This affords comparison of this type of therapy with those employed hitherto. No operative treatment has been used. Most of the ambulatory patients were put on crutches, and a lift was added to the shoe on the contralateral foot. In some instances, short periods of traction or immobilization in plaster were employed for the relief of pain and muscle spasm. During the last three years the preferred type of ambulatory treatment has been the use of crutches with a sling applied to the involved side, but no patient has yet completed treatment on this regimen alone. Therefore, this report is based on a study of twelve patients treated by bed rest and traction and fifty-four patients for whom therapy consisted chiefly in the use of crutches and a lift on the shoe on the contralateral foot.

Patients admitted to the Hospital for treatment by bed rest and traction were, with one exception, seen early in the course of the disease,—that is, as soon as diagnosis was confirmed by roentgenograms. In this series, as in other series reported, the x-ray appearance of the femoral head at the time of the first examination was not related to the duration of symptoms. Some patients seen one year or more after the onset of symptoms showed only condensation of the capital epiphysis with juxta-epiphyseal rarefaction, while some patients with symptoms of just a few weeks' duration showed marked flattening and fragmentation. Since it is believed that late end results will depend on the degree of alteration in the bony components of the hip joint, the stage of the disease and the results of treatment have been determined on the basis of the roentgenographic appearance of these structures.

Treatment during the period of hospitalization for this group of twelve patients consisted in continuous bed rest and the addition of five pounds of skin traction to the involved

FIG. 1-A

FIG. 1-B

extremity. The foot of the bed was elevated. In the three bilateral cases, traction was applied to both extremities, but in no instance was the extremity placed in a splint. Skeletal traction, by means of a threaded wire through the distal part of the femur, was tried in one case but was discontinued as impractical. In two instances traction in a lateral direction was added. In these cases, a five-pound weight was applied to a canvas sling about the thigh. This seemed to offer nothing of additional value, however, and was discontinued. Many types of skin traction were employed. The most efficient method proved to be the use of an adherent compound beneath broad strips of adhesive tape, held in place by elastic bandages extending from the malleoli to the mid-thigh. It was necessary to dis-

FIG. 1-C

FIG. 1-D

Case 11. These roentgenograms represent the average result obtained among patients treated by means of bed rest with traction. This patient was ten years old when treatment was started and had received no previous treatment.

Fig. 1-A: At initial examination changes characteristic of early Perthes' disease were obvious in the right hip. Continuous bed rest with five pounds of skin traction to the right leg was instituted.

Fig. 1-B: Six months later the greatest degree of deformity was revealed. There was no definite fragmentation of the capital epiphysis at any time.

Fig. 1-C: Twelve months after the institution of bed rest, regeneration was far advanced. Treatment with crutches and sling was substituted at this time.

Fig. 1-D: Appearance three months later. At this time the patient admitted that he had not been using the sling, and full weight-bearing was started.

FIG. 1-E

FIG. 1-F

Figs. 1-E and 1-F: Two years later an almost normal hip joint had been obtained.

continue traction for approximately one week in every month in order to control skin irritation. During this period, bed rest was still maintained. The patients were allowed the freedom of the bed, and they were permitted to sit up. As might be expected, they were often found on their knees, but this practice was discouraged as much as possible.

Treatment was continued throughout the period of degeneration and well into the period of regeneration, as advocated by Gill. The progress of the disease was followed by anteroposterior and lateral roentgenograms taken at intervals of two months. When it was felt that regeneration was far enough advanced, the patients were permitted to walk, with the use of crutches and a lift on the opposite shoe, or, since 1947, with crutches and the addition of a sling to the involved thigh. In bilateral cases, bed rest was enforced until at least one side had healed sufficiently to permit weight-bearing and until the opposite side was well regenerated. In this group of twelve patients the average period of treatment by bed rest and traction was 17.6 months. The shortest period of treatment was ten months and the longest was twenty-five months.

TABLE I-A

RESULTS OF TREATMENT WITH BED REST AND TRACTION

Case No.	Case	Age at Onset of Treatment (*Years*)	Previous Treatment (*Months*)	Type of Previous Treatment	Bed Rest and Traction (*Months*)	Later Ambulatory Treatment (*Months*)	Type of Later Ambulatory Treatment	Epiphyseal Index
1.	W. B.	3	0		15	9	Crutches and sling	47
2.	J. C.	4	0		20	12	Crutches and lift	50
3.	H. L.	5	0		10	13	Crutches and lift	40
4. (Bilateral)	K. N.	5	12	Modified bed rest	25		Still in traction	R. 31 L. 35
5. (Bilateral)	R. N.	5	0		28	6	Crutches and sling on right	R. 40 L. 49
6. (Bilateral)	B. B.	5	17	Crutches, braces, and lift-right	18		Still in traction	R. 40 L. 37
7.	J. T.	7	0		19	10	Crutches and sling	35
8.	D. H.	7	3	Crutches and lift	19	10	Crutches and sling	32
9.	J. F.	7	0		16	10	Crutches and sling	30
10.	D. W.	8	0		12	0		30
11.	L. B.	10	0		12	0		38
12.	J. M.	10	4	Crutches and lift	17	8	Crutches and sling	30
Average		6.3			17.6			37.6

The relative value of this method of treatment can be determined by comparing the end results obtained in this series of twelve patients with a comparable group of twelve patients treated by means of crutches and the addition of a lift to the opposite shoe. In selecting the group of twelve patients treated by the ambulatory method, we chose those with a comparable type of early involvement, and an effort was made to make the comparison favorable to this group. Of the fifty-four patients in the ambulatory group, however, only twelve could be selected who were seen early, who showed no appreciable initial deformity of the femoral head, and who appeared to be faithful in the use of their crutches and lift. However, most of the patients in this group were seen after the process had become well established, with definite deformity. It is felt that the efficiency of a method of treatment cannot be judged in such patients.

Of the twelve patients treated by bed rest, the nine with only one extremity involved are now walking without support. The patients with bilateral involvement are being handled with added precaution. Two are still at bed rest in the hospital, while the third is now using crutches and a sling for additional protection of one extremity. Regeneration is essentially complete in all instances, however, and unprotected weight-bearing could probably be instituted at any time.

The institution of treatment in each patient brought about a rapid alleviation of any pain and muscle spasm which was present. This improvement persisted and, when finally released from traction, each patient showed a full range of painless motion except for an occasional loss of a few degrees of internal rotation. In each case limb length was equal, but there was slight atrophy of the involved calf and thigh. In six patients the foot length was measured and the involved foot averaged three-sixteenths of an inch shorter than the normal foot. These measurements are of questionable significance but are mentioned since

FIG. 2-A

FIG. 2-B

it was noticed that a good shoe-fitting resulted in the use of a smaller size for the involved side.

While following the progress of the disease with x-rays at two-month intervals, it was noticed that the general course of the disease process remained unchanged. Each hip exhibited the usual order of condensation, fragmentation, and regeneration. However, the marked degree of fragmentation usually seen in the ambulatory cases was not seen in those treated by bed rest and traction. Since there is no great variability in the natural course of the disease, it was not felt advisable or practical to attempt an estimate of the time involved for each phase. In each case, however, it was noted that the greatest degree of flattening and fragmentation of the femoral head occurred early, and from this point on any change was one of progressive improvement. It was likewise noted, as Gill reported, that the onset of regeneration was relatively sudden and could be detected in the

serial films taken at two-month intervals. In no instance was there any evidence that prolonged traction interfered with regeneration.

In order to have some objective means of assessing the results of treatment, Eyre-

FIG. 2-C

FIG. 2-D

Case 19. These x-ray reproductions illustrate an average result obtained among patients treated by means of crutches with a lift on the shoe on the contralateral foot. The patient was first seen when he was seven years of age, and he had received no previous treatment.

Fig. 2-A: Relatively early Perthes' disease involving the right hip was found at initial examination. Treatment with crutches and a lift was instituted at that time.

Fig. 2-B: Appearance eight months later. Progressive flattening and fragmentation of the capital epiphysis are evident.

Fig. 2-C: Five months later there was evidence of some regeneration. Treatment by means of crutches and a sling for the right limb was substituted at this time.

Fig. 2-D: Appearance after thirty-one months of treatment. Unprotected weight-bearing was instituted at this time.

Brook devised the epiphyseal index. This is determined as follows:

$$\frac{\text{Height of the epiphysis}}{\text{Breadth of the epiphysis}} \times 100 = \text{Epiphyseal index}$$

He recognized that the disease involves both the epiphysis and the metaphysis, but felt that the shape and contour of the epiphysis reflected the condition of the metaphysis.

FIG. 2-E

FIG. 2-F

Figs. 2-E and 2-F: Appearance of the hip after three years. Note the increased flattening and broadening of the capital epiphysis and femoral neck.

He quoted as normal figures 45 to 55 for children below seven years of age, and 35 to 45 for children seven years and older. For purposes of comparison we have calculated the epiphyseal index for each of the group treated by bed rest with traction and the twelve control patients selected from the ambulatory group. Reference to Table I reveals an average epiphyseal index of 37.6; below seven years the average is 41.6 and above seven 35.3 for the group treated by bed rest. The control group averaged an epiphyseal index of 25.3; 29.2 below seven years of age, and 22.6 above seven years of age. These figures indicate that the average results are much

TABLE I-B

RESULTS OF AMBULATORY NON-WEIGHT-BEARING TREATMENT

Case No.	Case	Age at Onset of Treatment (*Years*)	Type of Previous Treatment (*Months*)	Type of Previous Treatment	Crutches and Lift (*Months*)	Epiphyseal Index
13.	W. C.	4	0		27	45
14.	N. W.	5	3	Spica	32	26
15.	M. B.	5	0		20	25
16.	W. D.	6	0		36 (With caliper last 20 months)	15
17.	L. D.	6	0		12	35
18.	L. M.	7	7	Walking caliper	34	19
19.	F. R.	7	0		31	23
20.	D. G.	8	0		52	14
21.	E. D.	8	0		18 (In spica 4 months)	32
22.	B. Z.	10	8	Intermittent bed rest	15	20
23.	F. M.	11	0		28	24
24.	J. B.	12	3	Skin traction	21	26
Average		7.4				25.3

Note: Table I-A and Table I-B show the comparative results in twelve patients who were treated by bed rest and twelve patients who were treated by ambulatory non-weight-bearing, and should be analyzed as one complete unit.

better in the group of patients treated with bed rest and traction. Of greater importance however, is the fact that with bed rest and traction an excellent result was obtained in each hip treated, whereas in the ambulatory group there was marked variability and only one excellent result. While the authors recognize that even with no treatment an excellent result is seen occasionally, they believe that the results presented here, those of Eyre-Brook, and those of Gill indicate that bed rest and traction represent the most desirable form of non-operative treatment for Legg-Perthes disease at this time.

The relative importance of the various factors involved in treatment by means of bed rest and traction is difficult to assess. Undoubtedly, bed rest is of greatest importance. The slight traction may be sufficient to diminish the intra-articular pressure resulting from normal muscle tone, and serve to limit the patient's activities. Its greatest value probably lies in the fact that it ensures the patient's remaining in bed. In this series of patients, traction was applied only to the involved extremity. Efficient traction to one extremity should produce abduction at the hip joint, and such abduction might serve as a deforming force. In this small group of patients, however, there was no evidence that traction produced such a deformity, since the results were excellent in all instances.

It is difficult to determine the exact time at which treatment should be discontinued. For this reason it has been the practice to continue bed rest until late in the stage of regeneration, after which ambulatory non-weight-bearing methods are substituted until regeneration of the femoral head is complete. Two patients treated with traction started walking immediately after twelve months of bed rest and suffered no ill effects. In reviewing the fifty-four patients treated by ambulatory means, it was noted that many patients started weight-bearing before regeneration was complete and suffered no subsequent increase in deformity. Eyre-Brook advocated from eighteen to twenty-four months of bed rest and allowed weight-bearing immediately; and his published roentgenograms reveal that regeneration was not complete when weight-bearing was resumed. It is felt, therefore,

that weight-bearing may be started when a smooth articular surface has formed and no major radiolucent areas are present in the epiphysis.

Among the considerations influencing the choice of treatment in Perthes' disease is the age of the patient at the onset of treatment. It is generally felt that the disease runs a more benign course in the younger age group. This may be because of the specific nature of the disease, or it may be because younger patients weigh less and subject the hip joint to less trauma. On the other hand the very young child is unable to cooperate with ambulatory treatment. It is felt, therefore, that the very young child is especially suitable for treatment by bed rest and traction.

The final consideration in this type of treatment is its feasibility. The expense involved makes it difficult or impossible to keep private patients in private hospitals for as long as two years for treatment of such a benign condition. In many of our clinics for crippled children, however, this type of prolonged hospitalization and therapy is easily possible, and the improved results obtained from treatment by bed rest and traction are sufficient to justify the continued use of this method. While such prolonged hospitalization may be impossible for private patients, complete bed rest in most instances can be carried out at home. Some private patients not included in this series have been treated with bed rest at home, but without the addition of skin traction, with the same excellent results. The success of such a program in the home is directly dependent upon the attitude of the parents and their willingness to cooperate.

SUMMARY

A comparative study has been made of twelve patients with Legg-Perthes disease treated by prolonged bed rest and skin traction, and an equal number treated with continued ambulation but with protection from weight-bearing by means of crutches and the addition of a lift to the shoe on the contralateral side. The twelve patients treated by the ambulatory method were chosen from a group of fifty-four patients thus treated during a ten-year period. An attempt was made to select patients for comparison who showed a similar type of involvement and who, at the time treatment was instituted, appeared to be in a comparably early phase of the disease.

This study shows a vastly improved early end result in the series of cases treated by prolonged bed rest. It is felt that bed rest and traction are the ideal form of non-operative treatment in patients who are seen before marked deformity exists, and that this treatment is especially suitable for very young children and those with bilateral involvement.

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CINEPLASTIC MUSCLE MOTORS FOR PROSTHESES OF ARM AMPUTEES*

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The history and the surgery of cineplastic muscle motors for the activation of arm prostheses has been well discussed by Nissen and Bergman, Kessler, and Alldredge. The purpose of this paper is to report our experience with the cineplastic procedure and the fitting of thirty patients at Walter Reed Army Hospital during the past two and one-half years.

Most of these patients were young males, ranging in age from eighteen to thirty-four, who had lost their arms from injuries sustained either during the active fighting in World War II or in accidents since World War II. Six patients had lost their arms as the result of injuries sustained in the Korean fighting. One patient, a child of six, had congenital absence of the right arm at the shoulder joint.

TABLE I

STATISTICAL SUMMARY OF CINEPLASTIC MUSCLE MOTORS

Type	Below-the-Elbow	Long Stump, Above-the-Elbow	Short Stump, Above-the-Elbow	Shoulder Disarticulation	Total
Biceps motors	16	7			23
Triceps motors	2*				2
Pectoral motors			5	2	7
Latissimus motors				1**	1
Total motors					33

* Placed in below-the-elbow cases. ** Holding tunnel in case with pectoral motor.

The cineplastic procedure was adopted for selected cases after it became apparent from work at the Army Prosthetics Research Laboratory that a terminal device, either a hand or a hook, could be developed which would provide better prehensile action than devices previously used and that a person provided with a muscle motor could get better use from these devices than with the usual shoulder-strap control.

It has been shown that the best muscles for this purpose are the biceps, the pectoralis major, the triceps, and the latissimus dorsi, since they could, by full development, produce enough power to activate most terminal devices. No experience has been had with the cinetization of other muscles; motors were not attempted in the forearm muscles because of their inadaptability for the motivation of the available terminal devices.

In this series, thirty-three muscle tunnels were made (Table I): Seven pectoral tunnels, twenty-three biceps tunnels, two triceps tunnels, and one latissimus dorsi tunnel. Sixteen of the biceps tunnels were made in below-the-elbow amputees and seven in above-the-elbow amputees. Five of the pectoral tunnels were made in above-the-elbow amputees with short stumps and two in patients who had had shoulder disarticulation. The child was provided with the latissimus dorsi tunnel for holding purposes. The two triceps tunnels were made in the first below-the-elbow amputees before the use of this muscle motor was considered unnecessary to activate the newer terminal devices.

All except two of our patients were cinetized from five weeks to eleven months follow-

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, February 1, 1951.

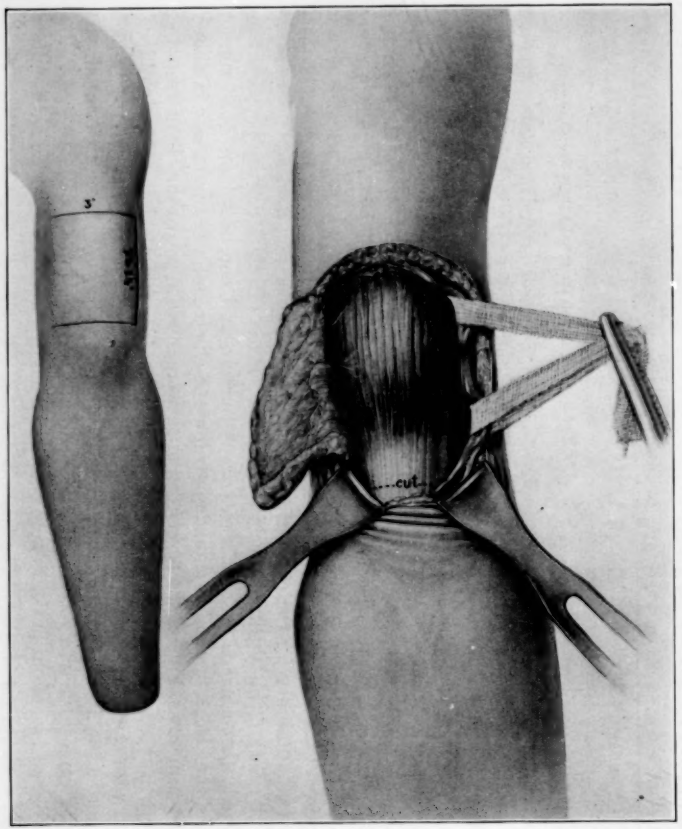

FIG. 1

FIG. 2

Fig. 1: To produce a tunnel with the largest diameter possible a skin flap of at least three inches and three and one-half inches on the three sides has been outlined. Note that the skin flap contains both subcutaneous fat and deep fascia.

Fig. 2: The flap becomes a skin tube by reversing the flap and suturing the sides. The muscle is then liberated from its distal attachment and the surrounding fascial septa. The tendinous end should be imbricated to provide a smooth non-adherent surface.

Fig. 2: The flap becomes a skin tube by reversing the flap and suturing the sides. The muscle is then liberated from its distal attachment and the [illegible] septa. The tendinous end should be imbricated to provide a smooth non-adherent surface.

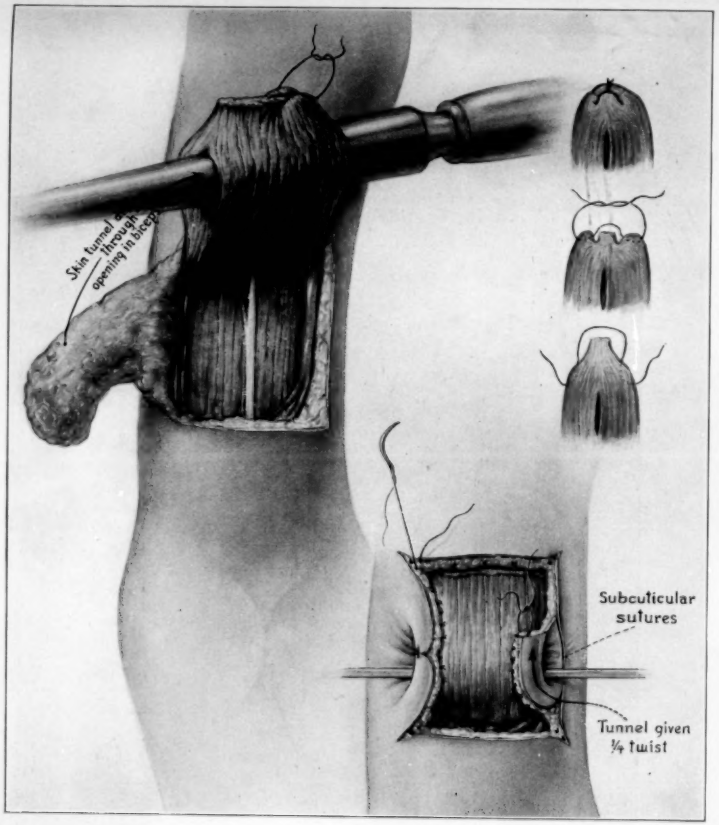

FIG. 3

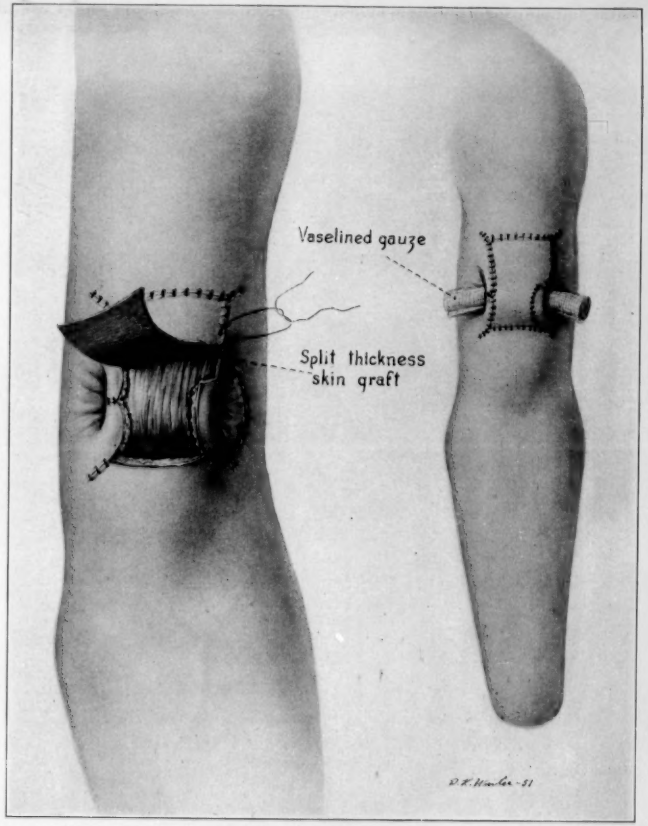

FIG. 4

Fig. 3: Incisions are made in the muscle, and the muscle belly should be slowly and carefully dilated to avoid damage to its fibers. The skin tunnel is then drawn through the opening and the mouth of the tube is sutured to the adjacent skin.

Fig. 4: A split-thickness skin graft of 0.015 to 0.020 inch is adequate to cover the exposed muscle surface. It should be noted that the distal end of the skin tube is well opened up over the muscle to shift the pin pressure from the suture line.

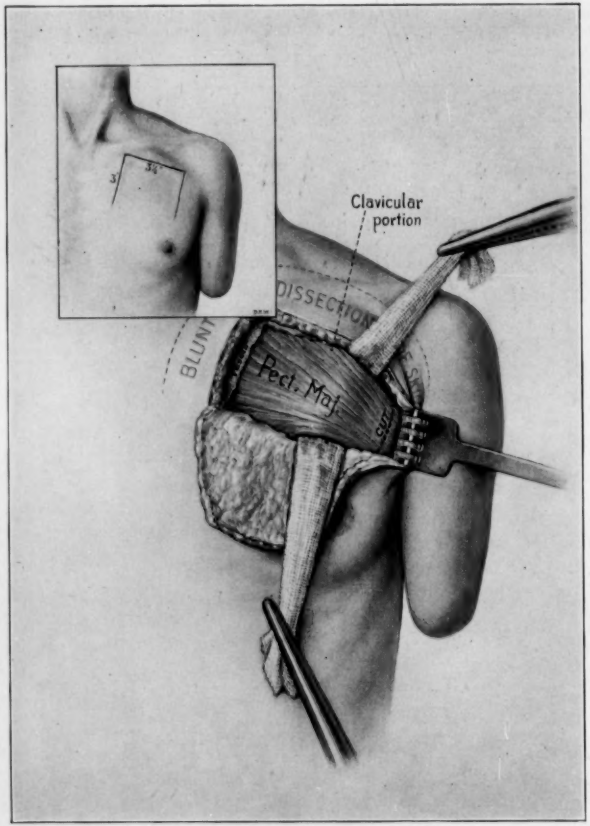

FIG. 5

FIG. 6

Fig. 5: The cineplastic procedure is much the same in the preparation of pectoralis motors as it is in the creation of biceps motors.
Fig. 6: A skin tunnel is created by reversing the flap and suturing the sides. Note the preparation of the tendinous end. The muscle belly is then slowly and carefully dilated to allow for the insertion of the skin tunnel.

fully dilated to allow for the insertion of the skin tunnel.

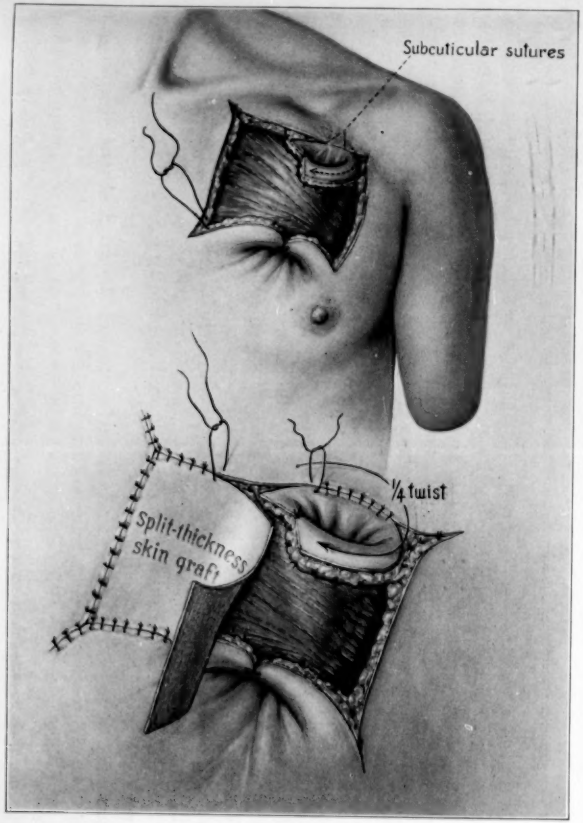

FIG. 7

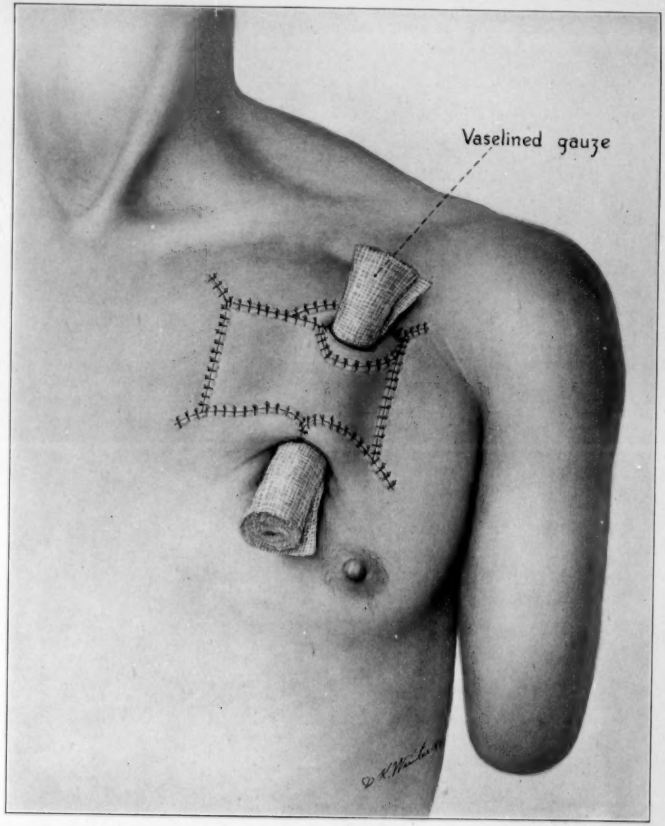

FIG. 8

Fig. 7: The skin tunnel is drawn through the opening in the pectoralis and the mouth of the tunnel is sutured to the adjacent skin. The denuded muscle is covered with a split-thickness skin graft.

Fig. 8: A small roll of vaselin or nylon gauze is inserted in the tunnel. After ten or fourteen days, exercise is started with a forceps attached to each end of the dressing in the tunnel.

ing the final revision of their stumps. The exceptions were the child with congenital absence of the arm and a below-the-elbow adult amputee whose forearm had been amputated six years previously.

Preoperative Care

Preoperatively, above-the-elbow amputees who were to be provided with biceps and pectoral motors were given supervised exercises to develop the muscles of the arm and shoulder. Since below-the-elbow amputees had normal biceps these exercises were not considered necessary for them. For the most part these patients were not given any supervised exercises, but were merely instructed to exercise the muscle while awaiting the complete healing of the amputation stump.

Surgical Considerations

The surgical procedure has been well described by Alldredge and other authors, but a few points should be reemphasized:

1. The muscle tunnels should be large. A skin flap of at least three inches and, preferably, three and one-quarter inches on the three sides should be outlined with particular care to produce a tunnel with the largest diameter possible (Fig. 1).

2. The skin flap should contain the subcutaneous fat and deep fascia to ensure a good blood supply (Fig. 1). The only tunnel lost had been freed subcutaneously and did not include the fascia.

TABLE II

STRENGTH AND EXCURSION OF MUSCLE MOTORS

Type	Strength of Motor (*Pounds*)	Range of Motion (*Inches*)
Biceps below-the-elbow	32 to 86	2 to 2¾
Biceps above-the-elbow	30 to 54	1½ to 2½
Pectoral	35 to 58	1¾ to 2

3. The muscle should be well liberated from its distal attachment and the surrounding fascial septa (Fig. 2). This should be done by cutting the fascial bands carefully and the tendinous attachments sharply. The tendinous end is carefully imbricated to provide a smooth non-adherent surface. Four of our earlier patients had to be subjected to a surgical procedure to free reattached bicipital tendons.

4. The distal muscle attachments can be easily detached through the incisions made for the skin tunnel (Fig. 2).

5. The muscle belly should be slowly and carefully dilated to avoid damage to its fibers (Fig. 3).

6. Hemostatis must be complete. If there is doubt, a drain, placed in the axilla for a pectoral tunnel or in the distal end of the wound of a biceps tunnel and removed in from two to five days, may prevent damage to an otherwise good tube or skin graft.

7. A split-thickness skin graft of 0.015 to 0.020 inch is adequate coverage for the denuded muscle area (Fig. 4).

8. The distal end of the skin tube should be well opened up over the muscle to shift the pin pressure from the suture line.

Figures 5 through 8 illustrate some of the features of the surgical procedure which provides the amputee with a pectoralis motor.

Anaesthesia

Although most surgeons have advocated the use of local anaesthesia for the entire operation, the author's procedure has been to make the original incision under local anaes-

FIG. 9

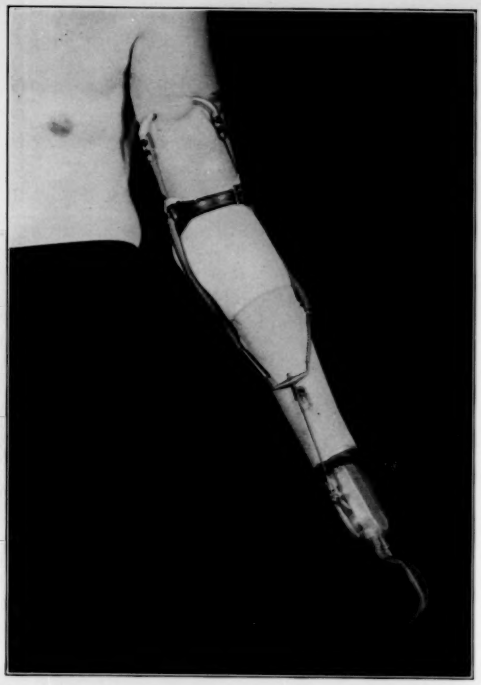

FIG. 10

Fig. 9: Photograph of an exerciser which is usually fitted to the stump three weeks after the operation.
Fig. 10: Below-the-elbow amputee with a long forearm stump is shown fitted with an Army Prosthetics Research Laboratory hook.

thesia. After the muscle has been exposed and the site for perforation determined, a shift is made to pentothal sodium. This allows for the careful separation of the muscles and an adequate anaesthesia for taking the split-thickness skin graft. There is no particular reason to continue on local anaesthesia after the muscle belly has been well defined and after its contraction has been demonstrated. Indeed, repeated local infiltration may jeopardize the flap margins.

Postoperative Dressing and Care

A small rolled tube of vaselin or nylon gauze is placed in the tunnel, and the skin graft is covered with a small piece of nylon or fine mesh gauze (Figs. 4 and 8). This dressing is not removed for ten to fourteen days, at the end of which time the non-absorbable sutures are removed. Exercise is then started with a forceps attached to each end of the dressing in the tunnel. This is continued daily at each dressing until the wounds are all well healed. A plastic pin of five-eighths to three-quarters of an inch in diameter is then inserted, and the muscle is exercised against resistance.

Exerciser

An exerciser is fitted to the stump about three weeks after the procedure (Fig. 9). This consists of a laminated plastic cuff placed over the end of the stump with rubber bands or springs attached to the pin. The exerciser is calibrated to measure the range of motion of the muscle motor, and the patient is encouraged to increase his range daily. Resistance is increased every few days until sufficient strength is obtained to activate a terminal device.

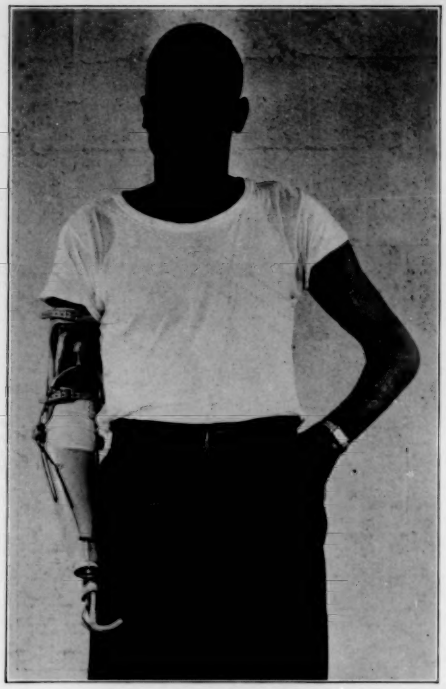

FIG. 11

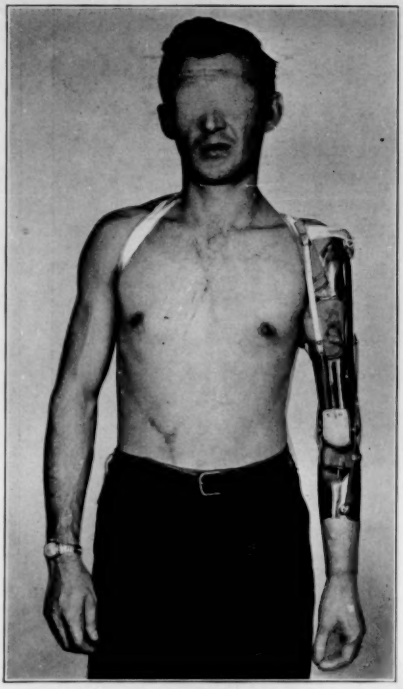

FIG. 12

Fig. 11: Prosthesis of a below-the-elbow amputee with a short forearm stump is shown fitted with external joints at the elbow. The prosthesis is fitted with a Dorrance hook.

Fig. 12: Above-the-elbow amputee has been fitted with an Army Prosthetics Research Laboratory light metal arm with a hand and glove.

After-Care of Tunnel

Daily cleaning with soap and water is usually sufficient to care for the tunnel. Small alcohol sponges may be used in cleaning the tunnel, but talcum powder produces irritation and should be avoided. A little emollient may be needed to introduce the pin initially; later, a little moisture or alcohol is sufficient.

Results of Surgery

Two tunnels were considered surgical failures. A biceps motor in a below-the-elbow amputee was ineffective when the skin tunnel was lost because of the failure of maintaining a blood supply to the flap; and a triceps motor failed because of continued irritation in the local scar tissue. Both of these were later closed. The patient whose biceps motor failed was fitted with a conventional arm, and the patient who lost his triceps tunnel was provided with an excellent biceps motor and has become one of the most successful of our cases. Another biceps tunnel in a poorly selected above-the-elbow amputee was considered unsuccessful and was never used because of excessive scarring around the tunnel ends. Twenty-eight have well healed muscle motors and have been fitted with either a prosthesis or an exerciser.

Of the twenty-four patients fitted with suitable prostheses, twenty-two are using their muscle motors to activate their terminal devices.

Strength of Motors

The strength of the biceps motors in below-the-elbow amputees varied from thirty-two to eighty-six pounds; only two motors had a strength of less than fifty pounds, while

FIG. 13

Fig. 13: Child afflicted with upper-extremity agenesis is shown with prosthesis attached to pectoral motor. The child's muscle motor is still too weak for an ideal arm.

Fig. 14: Patient has short above-the-elbow stump; his prosthesis is attached to a pectoral motor.

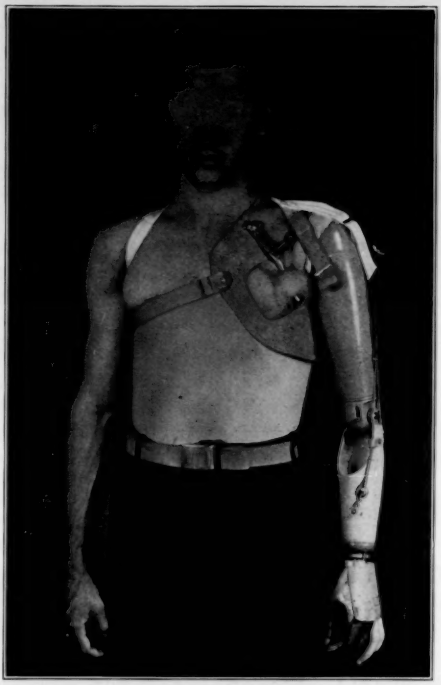

FIG. 14

five had a strength of seventy pounds or more. In above-the-elbow amputees, strength varied from thirty to fifty-four pounds (Table II). As approximately 55 per cent. of the power of these muscles can be transmitted to the hook or finger tips and as only fifteen pounds is needed there, it is evident that all these motors had adequate strength.

The pectoral tunnels in the adults varied from thirty-five to fifty-three pounds in strength. The child's tunnel had a strength of eight pounds with a gradual increase from initial imperceptible power. As only 40 per cent. of this power is transmitted to the terminal device, the child's muscle motor is still too weak for an ideal arm; the others are adequate.

Range of Motion

The biceps motors in below-the-elbow amputees have a range of from two to two and three-quarters inches, the biceps motors in above-the-elbow amputees of from one and one-half to two and one-half inches, and the pectoral motors of from one and three-quarters to two inches (Table II). The child's pectoral motor has a range of one and one-eighth inches. Most terminal devices require a minimum range of one and one-half inches for optimum function.

Construction of the Pin

The first patients were fitted with aluminum pins curved to maintain the centering. These were easily machined in the desired shape, but they became pitted after use and irritated the tunnel. All our pins are now made with acrylic plastic over a wire cable, molds being taken of the tunnel to ensure an accurate shape. The pins are curved distally on each end to keep each centered in its place. If a tunnel should be slightly oblique, the end of the pin may be curved to compensate for the obliquity.

Fitting of Prosthesis

As soon as a muscle motor has obtained a fair range of motion and strength, the prosthesis is fitted to the amputee. It usually took from six to eight weeks after the operation for a muscle motor to gain a sufficient range of motion and strength.

For a below-the-elbow amputee, with a long forearm stump, the only prosthesis needed was a well-fitted plastic socket and a small strap just above the elbow to fix a reactor point (Fig. 10). In shorter stumps, flexible cables or straps to a cuff around the upper arm with straps above and below the tunnel may be necessary (Fig. 11). For below-the-elbow amputees with extremely short stumps, external metal joints are required. These amputees can be fitted with any conventional artificial arm, however, with allowance for attaching the activating cable of the terminal device to the biceps tunnel rather than to the opposite shoulder.

Above-the-elbow amputees need a conventional prosthesis with an opening in the socket (Fig. 12) to allow for the attachment of the muscle motor to the cable.

Patients provided with pectoral muscle motors require the greatest ingenuity on the part of the limb maker (Figs. 13 and 14). The reactor point should be so placed as to transmit the power in the direction of the arm rather than toward the shoulder cap.

Terminal Devices

Of the twenty-four patients fitted, eleven were fitted with the conventional Dorrance hooks, three with functional hands only, and ten with functional hands and interchangeable positive closing hooks.

Dorrance hooks have been used for a long time as a terminal device and are still considered to be useful. With a muscle motor, the amputee has better control over the closing of the hook and has more independent use of his cinetized extremity. Conspicuous shoulder shrugs are avoided.

A positive or voluntary closing hook developed at the Army Prosthetics Research Laboratory (Fig. 10) has a compensating mechanism that allows the muscle to utilize its strength throughout its entire range. This compensating mechanism enables the optimum use of muscle power and replaces some of the lever action across joints which gives normally attached muscles their strength in a shortened position. As the hook closes during the contracting phase of the muscle action, it closely replaces the grasping action of a normal hand. The action of closing is under control at all times, and the pressure applied to an object can be controlled to within a fraction of an ounce. The opening of the hook is accomplished with a spring which replaces the extensor mechanism more satisfactorily than an extensor muscle motor. Equipped with this terminal device, the amputee develops a sense of "feel" of the size and of the consistency of the object grasped. He is able to handle many small objects with greater dexterity.

Hands, also developed at the Army Prosthetic Research Laboratory (Figs. 12 and 14), have a similar mechanism controlling the first two fingers and the thumb. Although it is not as adaptable for all uses as the hook, it produces a functional replacement which is hard to detect.

ADVANTAGES OF MUSCLE MOTORS

The advantages of cineplasty, as listed by our patients, are:

1. A sense of "feel" and position is transmitted from the terminal device;
2. Freedom from a harness to the opposite shoulder provides more comfort;
3. The independence of the extremity gives a better coordination to bilateral activity;
4. The terminal device can be activated in any position;
5. The terminal device can be activated without conspicuous motion.

NOTE: Acknowledgment is made to the Medical Illustrative Service of the Armed Forces Institute of Pathology for the drawings and to the Army Medical Center for the photographs.

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DISCUSSION

DR. RUFUS H. ALLDREDGE, NEW ORLEANS, LOUISIANA: Col. Spittler's work at the Walter Reed Army Hospital with the cineplastic method is a culmination of one phase of the research and developmental program which began several years ago. He has demonstrated from a practical standpoint several important points, all of which are prerequisite to the successful use of the cineplastic method in upper-extremity amputations.

As a result of the findings of the European Commission on Amputations and Artificial Limbs in 1946, the Committee on Artificial Limbs of the National Research Council began a research program on cineplasty. A complete analysis of muscle mechanics and physiology of the cineplastic muscle motors resulted in the plotting of fundamental data which supplied the surgeon, the engineer, and the limb fitter with the necessary requirements for improved prostheses. This has been a long and arduous task. The research and developmental work which was undertaken by the Committee on Artificial Limbs is still continuing with gradual improvement resulting in the design and the application of the prosthesis to the cineplastic muscle motors.

As a result of all of this research, the surgery of cineplasty is now on a sounder basis than it has ever been. The design, development, and fitting of the prosthesis has been immeasurably improved. The research has changed or modified to some extent every phase and aspect of the cineplastic method. At the same time, there have been continual improvements as a result of the same research effort in the conventional types of prostheses. For these reasons it is more necessary than ever before that the surgeon, the engineer, and the limb maker work together as a team and that they have a complete knowledge and understanding of all aspects of the problems of upper-extremity amputations.

Although the cineplastic method has been improved in every aspect, it is still a method which will of necessity remain limited in its usefulness for some time to come. The method requires a careful selection of cases and the use of a precise surgical technique which will give perfect results in an extremely high percentage of cases. Adequate preoperative and postoperative care of the patient, carefully coordinated with a skilled limb fitter, in a center which has all of the facilities for the complete fitting of the prosthesis, and thorough training of the amputee are the minimum requirements for the use of this method.

At present there are very few centers in the country where even these minimum requirements can be met. The Walter Reed Army Hospital is the leading example of such a center in the world today. The practical results of Col. Spittler's application of all of the fundamental principles prerequisite to the success of the method speak for themselves and indicate the absolute necessity of having all of the facilities necessary for the use of the method before proceeding with cineplastic surgery on any patient.

I have been personally interested in seeing from time to time and following some of Col. Spittler's cases. The results of his work are encouraging and heartening to all of those who have been interested in the Amputation Artificial Limb Research Program. He is to be congratulated upon his understanding and approach to the problem and upon his results. Except for the excellent work Col. Spittler has demonstrated in this Center, the research work might not have resulted in any practical benefits for many years to come or, worse still, this important and improved method might well have again fallen by the wayside.

DR. HENRY KESSLER, NEWARK, NEW JERSEY: Experience of twenty years and more in the field of cineplastic surgery has convinced me of its value. Col. Spittler's presentation today confirms that conviction. These results, and they are brilliant results, could not be obtained alone. The previous speaker has already emphasized the importance of integrated teamwork. Excellent results require the proper selection of the patient, his briefing, and his cooperation; they require also well executed operations, a well constructed prosthesis, and training in the use of the prosthesis. This is the sort of integrated program we refer to when we use the word "rehabilitation". In the cases presented by Col. Spittler, the ages range from eighteen to thirty-four, but I think we should not get the impression that cases like these are confined to that age group. In my series, the age group ran from three and one-half to sixty-five years of age. Many women were also included.

Cineplasty has a much wider field of usefulness than is indicated by the use of pectoral motors and biceps motors alone. I do hope that Col. Spittler will proceed to the application of cineplasty to the forearm. Unfortunately, he, like many of us, is a prisoner of the engineers and of those investigators who are obsessed with the idea that a cineplastic motor must have considerable power. The cineplastic motor has other functions besides that of innate strength. Neuromuscular control is, in my opinion, indispensable. One of my patients, for example, was a pianist before he lost his arms in the war, and he was anxious to return to the concert stage. This was asking for a little too much, but he required some device which would give him the

(*Continued on page 632*)

NEW CINEPLASTIC PROSTHESIS *

BY COMMANDER THOMAS J. CANTY, *Medical Corps, United States Navy*

From the Navy Amputation Center, U. S. Naval Hospital, Oakland, California

The cineplastic procedure in amputation surgery was first described by Vanghetti of Florence, Italy, in 1898. In 1905, Ceci presented the original case of a cineplastic operation in the lower third of the arm which had been fitted with a prosthesis constructed by the orthopaedist Redini before the Italian National Surgical Congress in Pisa[6].

In Germany, Sauerbruch made a special study of the whole idea of cineplasty, publishing his reports in 1916. This surgical procedure was introduced in the United States by Kessler, who summarized Sauerbruch's work in 1939. Nissen and Bergmann published a short monograph on this subject in 1942, and in 1948 Alldredge published a paper on the cineplastic method in upper-extremity amputations.

The surgery of the cineplastic procedure has been well worked out, and the description of the technique in Kessler's book, *Cineplasty*, published in 1947, affords an indispensable practical guide.

FIG. 1

Biceps motor on below-the-elbow stump. (Official U. S. Navy photograph.)

Lebsche in Munich introduced a modification in the technique in 1943. He practised liberation or division of the distal insertion of the muscle through which the tunnel was placed. This resulted in allowing a greater excursion of the muscle tunnel and is, therefore, an important contribution to the cineplastic procedure.

At the Navy Amputation Center, cineplastic surgery has been performed on forty-seven amputees. The experience gained from these has shown that the cineplastic muscle motor provides an excellent means for operating an artificial hand or hook.

Prostheses available at present are essentially the same as those developed by Sauerbruch and his associates about thirty-five years ago. These devices, however, lack many desirable cosmetic, functional, and mechanical features. Recently, improvement on the Sauerbruch prosthesis has been made by Eberle in New Jersey, who has developed a hook for the cineplastic prosthesis which is interchangeable with the artificial hand. It has long been realized that there has been a definite need for much improvement in cineplastic prostheses [1].

Fundamental studies on muscle physiology in the cineplastic muscle motor have been conducted by Inman and others at the University of California under a research project of the Committee on Artificial Limbs of the National Research Council. This work has shown that the biceps and pectoral motors provide the greatest power and excursion.

At this Center, bilateral above-the-elbow amputees have been provided with bilateral pectoral motors. Although biceps motors may be provided for amputees with suitably

* The opinions set forth are those of the author and are not to be considered as reflecting the policies and views of the Navy Department or the Naval Service at large.

long above-the-elbow stumps, pectoral motors are considered superior. Recently, biceps motors have been provided for patients with below-the-elbow amputations (Fig. 1). A tunnel excursion of as much as from two and one-half to four inches and a power as great as from forty to sixty pounds have been observed in biceps and pectoral motors (Figs. 2-A and 2-B).

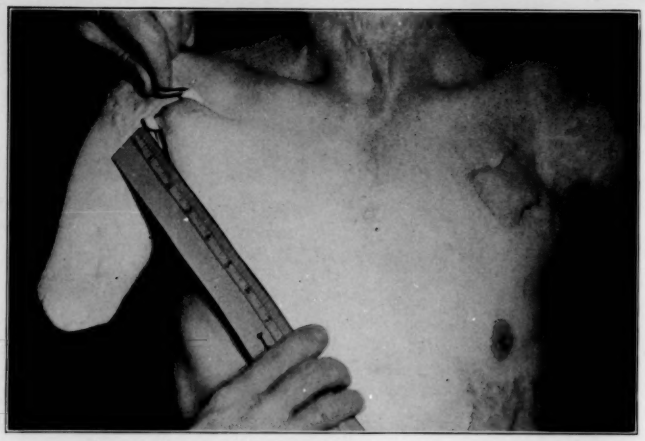

FIG. 2-A

FIG. 2-B

Pectoralis cineplastic motors showing an excursion of four inches. (Official U. S. Navy photographs.)

Principles of simplicity, durability, light weight, alignment, proper cosmetic appearance, and proper fitting of a comfortable socket, together with economical manufacturing costs, have all been important considerations in the development of new cineplastic prostheses. It is further felt that cineplastic prostheses should be developed which any qualified limbmaker could manufacture, thereby obviating the necessity for a special and expensive prosthesis.

In the transmission of power from the motor to the distal appliance, the Boden cable is utilized; this device has recently received wide acceptance. The efficiency of the cable is relatively good and is a considerable improvement over the conventional rawhide or leather thong.

In making below-the-elbow prostheses, utilizing a biceps motor, the socket and forearm shell are constructed over a plaster reproduction of the stump. Poly-ester styrene is used as the plastic, and cotton stockinette as the laminae. An aluminum wrist coupling is fitted at the terminal end of the forearm shell. Other types of materials may be substituted for the plastic, including fiber, aluminum, wood, leather, and steel. The biceps cuff is open anteriorly and made from a sheet of spring steel covered with leather.

At the elbow joint there is provided a simple hinge joint which is attached above to the biceps cuff. The distal solid stay is replaced by a plastic covered cable which is, in turn, attached to the central part of the forearm shell. This arrangement allows the patient to use his own remaining powers of pronation and supination. A curved, stainless-steel peg, an improvement over the straight ivory peg because it more closely follows the natural contour of the tunnel, is attached to the cable. A swivel attachment for the cable housing

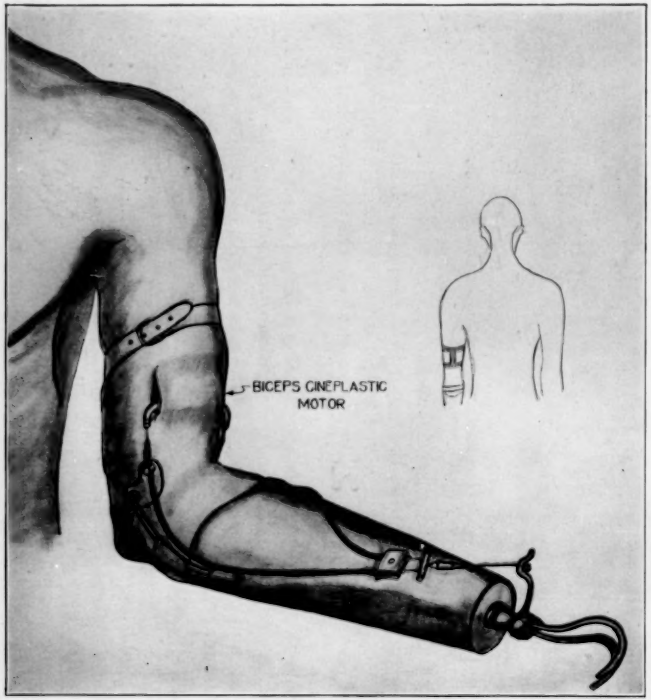

FIG. 3

Below-the-elbow cineplastic prosthesis with dual cables to the hook. (Official U. S. Navy drawing.)

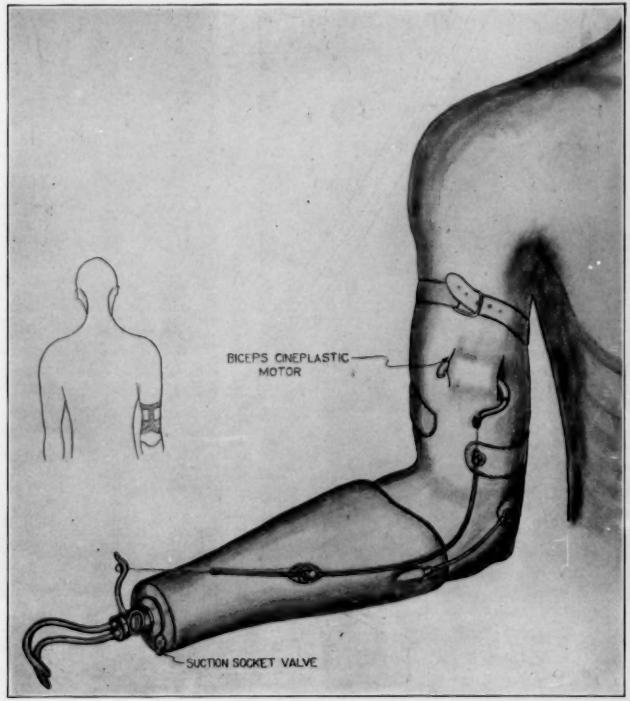

FIG. 4

Below-the-elbow prosthesis with single cable to hook. (Official U. S. Navy drawing.)

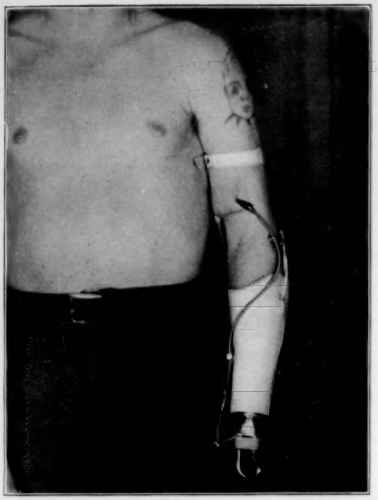

FIG. 5-A

FIG. 5-B

Views of below-the-elbow cineplastic prosthesis. (Official U. S. Navy photographs.)

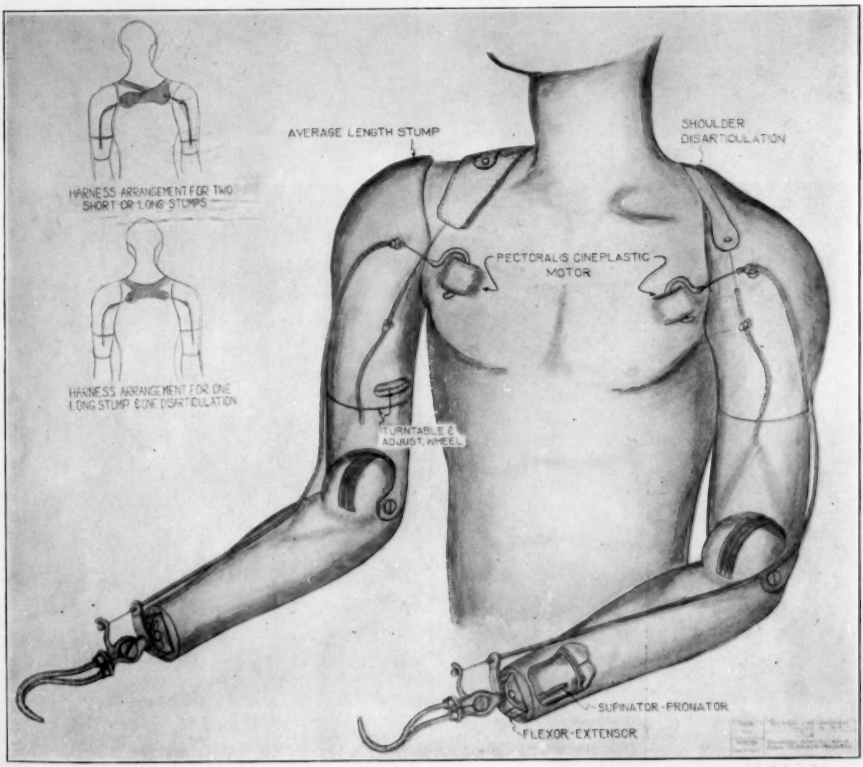

FIG. 6

Pectoralis cineplastic motors activate prostheses in bilateral above-the-elbow amputee. (Official U. S. Navy drawing.)

is provided at the distal portion of the biceps cuff, and the two cable housings are again joined on a swivel at the distal third of the forearm shell. This allows for manual rotation of the hook or hand. The proximal end of the cable is detachable from the curved peg by means of a small shaft, ending in a small metal ball. By this means, a break-away is provided as a safety factor in case the wearer should be unable to release his prosthesis

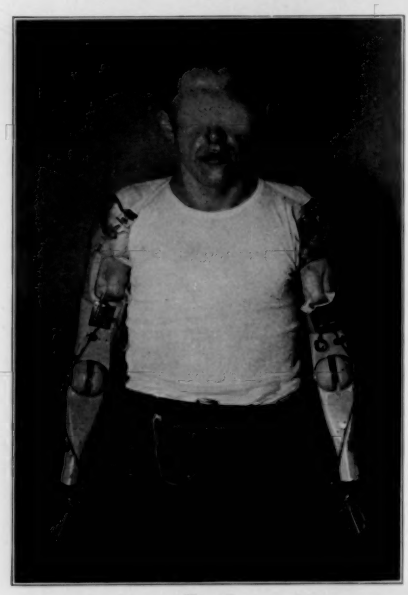

FIG. 7

FIG. 8-A

FIG. 8-B

FIG. 8-C

Fig. 7: Bilateral above-the-elbow amputee provided with biceps cineplastic motors. (Official U. S. Navy photograph.)

Figs. 8-A, 8-B, and 8-C: Bilateral above-the-elbow amputee with pectoralis motors operating Navy-Fitch arms. (Official U. S. Navy photographs.)

from a moving object. This feature allows the prosthesis to be pulled completely off the arm without injury to the muscle tunnel. The completed prosthesis, including the hook, weighs approximately one and one-half pounds (Fig. 3).

A modification of the double cable control, which has been very satisfactory under tests, is to use a single cable including the break-away. This arrangement appears to be more satisfactory in that the amount of cable and housing is reduced and greater simplicity is secured (Fig. 4).

The amputee fitted with the prosthesis may operate his hook in any position possible with the natural hand. No shoulder harness of any type is required, and his hook is under his instantaneous neuromuscular command at all times (Figs. 5-A and 5-B). Fitting with the cineplastic prosthesis does not restrict the amputee to the exclusive use of that type of prosthesis,—he may also be fitted with conventional types without difficulty.

Above-the-elbow amputees who possess cineplastic motors are fitted with the Navy-Fitch prosthesis, and the pegs through the pectoral or biceps motors are attached directly by means of the cable to the hook or hand (Figs. 6 and 7). This particular type of prosthesis may also be equipped with a turn-table above the elbow and devices for providing pronation and supination as well as flexion and extension of the wrist.

With bilateral above-the-elbow amputees, the operation of the prostheses in excess of four shoulder motions is considered undesirable. The complexity of controls and harnesses is understandably objectionable to the amputee because of the unnatural and grotesque motions of the shoulder required. Actual performance studies of the bilateral arm amputee indicate quite conclusively that, when equipped with appropriate cineplastic motors (Figs. 8-A, 8-B, and 8-C), the required shoulder motions allow him to operate his prosthesis in a more efficient and natural manner.

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ANALYSIS OF ONE HUNDRED AND TWENTY-FOUR SUCTION-SOCKET WEARERS FOLLOWED FROM SIX TO FIFTY-FIVE MONTHS*†

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The history and development of the suction socket, the indications and contra-indications, and the principle governing the construction of the prosthesis have been well described in the literature [2, 4, 5, 9, 10, 13, 14].

The earliest suction sockets made in the Los Angeles area of which we have knowledge were those constructed by Northrup Aircraft, Incorporated, in 1946. This organization was interested in the development of a plastic prosthesis and made plastic suction sockets for ten patients (Fig. 1).

FIG. 1

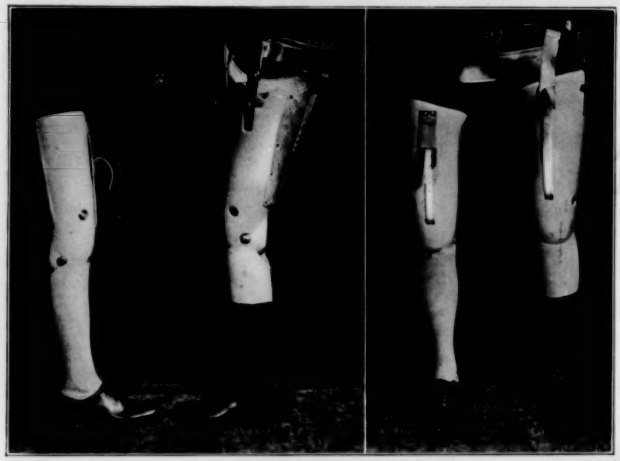

FIG. 2

Fig. 1: An early model plastic suction socket, showing prominent ischial seat and lateral projection above the trochanter. The valve is seen at the bottom of the socket.

Fig. 2: Anteroposterior and lateral views of the suction socket (left) and of the conventional prosthesis (right). The valve and the absence of hip-joint and pelvic belt are seen on the suction-socket prosthesis.

In the fall of 1947, a school was held under the auspices of the National Research Council and the Veterans Administration, at the University of California [9] for the purpose of instructing and training selected surgeons and limb fitters in the construction and in the use of the suction socket. Following this, schools were organized and conducted in several centers throughout the country. Schools were held in Los Angeles under the auspices of the Veterans Administration and National Research Council in December 1947 and January 1948. In July 1948, a clinic for suction-socket wearers was established at the

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, February 1, 1951.

† Sponsored by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Regional Office of the Veterans Administration in Los Angeles. Most of the work which is reported here was done through this Clinic.

GROUPS OF CASES

The cases in this study are composed of three groups of patients:

Group I consists of eighty-five patients who have been provided with suction sockets through the combined Veterans Administration and National Research Council program.

Group II includes thirty-four patients seen by us who had been fitted with suction sockets by private physicians, insurance companies, or limb manufacturers not included in this program.

Group III consists of ten patients who were fitted in 1946 with plastic suction sockets developed by Northrup Aircraft, Incorporated. These have been followed from forty-eight to fifty-five months. (One man is now included in Group I.)

Analysis of Group I

Of the eighty-five patients in this group, one was a woman. Their ages varied from twenty-three to sixty-nine with eleven patients over thirty-five years of age. The follow-up period on these patients has been as follows: Twelve patients were followed from six to twelve months, forty patients from one to two years, twenty-three from two to three years, and ten for over three years.

These patients were selected with care, and special attention was given to their emotional stability. In the first year or so of the program, only those patients with presumed ideal stumps were fitted. Experience showed, however, that other stumps could be satisfactorily fitted; hence, individuals with more complicated fitting problems were accepted.

Seventy-two of these eighty-five patients are successfully wearing suction-socket prostheses (Fig. 2). None was satisfactorily fitted with the first socket without some alterations or modification. These averaged three or four to each socket, while some required many more. Bechtol has emphasized the need for frequent modifications [1]. In thirty of the seventy-two, a second socket was necessary before a satisfactory fit was obtained. In four instances, three sockets were necessary. A good many of the sockets which were made early in the program proved unsatisfactory because of inadequate construction and fitting.

Thirty-five of the seventy-two patients have had only one socket. These were made later in the program and reflect the accumulated experience which now enables a better initial fitting to be obtained.

Only two patients fitted in the past year have required a second socket because of improper construction of the first socket. Thirteen of the eighty-five patients were unsuccessfully fitted. These men dropped out of the program for various reasons: One moved from the area; three were unable to devote the necessary time to obtain alterations and to attend the follow-up clinics. Eight simply did not cooperate; they apparently expected immediate success from this type of prosthesis, and either would not or could not devote the necessary time and effort to become successful wearers of the prosthesis. One, who had an extremely short stump, is a commercial pilot. Since he lost suction when sitting, he felt that the conventional type of prosthesis was better for him in this work.

Six individuals, who were fitted early in the program, were not satisfied, and they dropped out for varying periods of time. They later returned to the program, were well fitted, and are among the seventy-two satisfied wearers.

Analysis of Group II

Thirty-four patients who were fitted by either physicians or limb fitters outside the Veterans Administration program have been seen by us. These patients had worn suction sockets for six to thirty-six months; twenty-one were satisfied wearers. Seventeen were

thirty-five years of age or older. In four of six insurance cases, the patients became successful wearers. One was a girl eleven years old.

These patients had had the same problems as those in Group I. In general, however, their difficulties were usually more pronounced. A number exhibited persistent oedema of the stump after six to eight months of wearing the suction-socket prostheses. Several of these people had not been followed, and others had had an insufficient follow-up. A few had purchased the prosthesis from a limb shop without having seen any doctor.

Analysis of Group III

Of the ten men for whom Northrup Aircraft, Incorporated, made their first plastic suction sockets in 1946, only four still wear suction-socket prostheses.

The first of these, a salesman thirty-one years old, despite discouraging ischial irritation and oedema, has maintained his enthusiasm for the suction socket. He is wearing his third socket, but he is still not entirely satisfied. He needs a new one with more room distally.

The second, a salesman forty-two years old, wore his suction socket for approximately two years before going back to a conventional prosthesis. The advantages of the suction socket, however, were so apparent to him that he asked to be included in the Veterans Administration program. Fourteen months ago, his plastic socket was replaced by one of willow wood, and he is now a satisfied wearer.

The third patient, a lawyer, thirty-eight years old, now wearing his third plastic socket, had been a satisfied wearer for four years until a few months ago. An allergic dermatitis of the stump was caused by the lacquer finish of the socket, and for this reason he is not now wearing the suction-socket prosthesis. This patient had played a great deal of tennis and golf while wearing the suction socket.

The fourth patient is a former marine, now a student counselor. He is thirty-eight years old and weighs 220 pounds. He has been followed longer than any other in this series, and has been an enthusiastic suction-socket wearer for fifty-five months. He is an avid fisherman and is now wearing his twelfth socket. His stump has increased five inches in circumference during this time. He has experienced and has successfully overcome the complications which were experienced by other members of the group. At first, he had difficulty with ischial irritation, and many adjustments to the ischial seat were necessary until a satisfactory fit was obtained. Then he discovered that the high prolongation of the socket laterally was unnecessary. He had had a great deal of trouble because of choking at the end of the stump, which was caused in part by the increasing circumference of the stump as the muscles developed and in part by the fact that, at the distal end, insufficient room had been provided.

The remaining six patients of this group have been unable to obtain satisfactory fittings and have returned to conventional prostheses.

DISCUSSION

There are several generalizations which can be made from the study of these groups. In our experience, the indications for a suction-socket prosthesis are: for any stump with more than four inches of femur, measured from the adductor tubercle of the pubis to the bone end, in which no active infection, dermatitis, large tender bony spur or scar, and no advanced circulatory impairment is present. Small spurs are not a contra-indication. Long stumps (Gritti-Stokes or Callender) are less suitable, because the socket must be long, which interferes with the placement of the knee mechanism. Painful scars which cannot be resected are a contra-indication. It is necessary for the individual to be emotionally stable, and to desire rehabilitation and independence. He must also have the perseverance necessary to adapt himself to this type of prosthesis, and he must be willing to expend the time and effort which successful fitting demands.

Patient's Reaction

Those patients who have carried on with the suction-socket prostheses have been quite consistent in their reactions to it. They have invariably stated that they prefer the suction socket to a conventional type because:

1. This prosthesis feels more like an integral part of the person;
2. It is easier to control, particularly in rotatory movements;
3. It provides greater freedom of motion;
4. The prosthesis feels lighter;
5. The piston action of the stump in the bucket is largely eliminated;
6. The prosthesis eliminates the pelvic belt, shoulder harness, and stump socks, as well as the increased perspiration associated with these;
7. The prosthesis causes no bulges beneath the clothing;
8. Those patients whose adductor rolls have disappeared with the use of the suction socket are cognizant of this added comfort.

Complications

Ischial Irritation

Practically every patient in this series has complained of some ischial irritation at the outset. This appears to have been less severe in those individuals who had had a well fitted conventional prosthesis with partial ischium-bearing. Modifications of the ischial seat to conform to the needs of the patient and some fortitude on the part of the patient himself have solved this problem. In this connection, it has been found that partial end-bearing, in those stumps which will tolerate it, relieves some of the ischial pressure. The ankle, with lateral motion, permitting about 15 degrees of rotation, has proved beneficial in this regard. Practically all the patients who have worn this type of ankle have felt that this factor is of some importance. Sooner or later, however, almost all of the men have gone back to the conventional type of ankle joint, because the ankle with lateral motion does not stand up mechanically. It requires constant repairs, necessitating absence from work.

Oedema

Of the patients in Group I, 40 per cent. have complained of oedema, while in the other two groups, about 60 per cent. have complained of oedema. The causes and remedies of oedema will be discussed in the section devoted to the construction of the socket.

Other Complications

In a few individuals, pressure in the adductor region or over the glutaeus maximus occurred. Loss of suction was seen in about 10 per cent. of the cases, which, except in the extremely short stumps, was a fitting problem. Folliculitis and dermatitis have been troublesome in a few isolated instances, but have been corrected by dermatological treatment. In our experience, perspiration has been a minor problem; in only three patients has it been severe. Formerly, silica gel, a hygroscopic agent, was used in an effort to lessen perspiration. However, a 20 per cent. solution of aluminum chloride, applied to the stump every three or four days, is more effective in controlling perspiration. To control the yeast and fungus growth which produce a foul smelling socket, the socket (not the stump) should be washed with 2 per cent. formalin solution, followed with alcohol, at weekly intervals.

Injuries to the Opposite Extremity

In several instances in this group of cases, wearers of suction-socket prostheses had severe injuries to the opposite extremity, such as a fused knee, a below-the-knee amputation, malunion of femur or tibia with a resulting deformity. These disabilities have not interferred with the use of the suction socket, and they are not, therefore, considered contra-indications.

CONSTRUCTION OF THE SOCKET

The general principles and errors in construction of the suction socket have been discussed elsewhere [2, 3, 4, 8, 9, 10, 13, 14]. Mistakes have been discovered by trial and error, and may now be avoided. Two points, however, in the construction (Fig. 3) and the fitting should be emphasized.

The first point concerns the ischial seat (Fig. 4). Early in the suction-socket program, it was believed that the ischial seat should be high, wide, and flat. In many instances this caused excessive irritation, so the seat was modified by lowering it, decreasing its width, rounding its anterior surface, and extending it laterally to permit some gluteal weight-bearing. It was found, however, that the tuberosity tended to slide forward off the seat, causing pressure in the adductor region and over the femoral triangle, with discomfort and an obstruction to venous and lymphatic return. The lateral prolongation was also found to crowd the gluteal muscles, which produced too much pressure anteriorly when the glutaeus maximus was contracted. The sockets recently constructed have, therefore, been made with the ischial seat relatively flat, fairly wide, well to the medial side, and directly beneath the tuberosity. That the seat be directly beneath the tuberosity is the cardinal requirement.

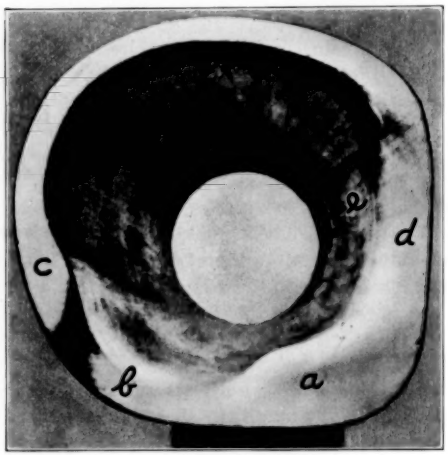

FIG. 3

The second point relates to the shape of the socket. The general belief at the start of this program had been that the suction socket should fit the stump snugly. As a result of this close fit, the distal ends of some stumps were choked, and the patients suffered from the resulting oedema. It is our belief that the most important cause of oedema is this choking of the lower end of the stump. Therefore, sockets are now made somewhat barrel-shaped, with a snug fit circumferentially for two and a half to three inches at the top, and with contact between the socket

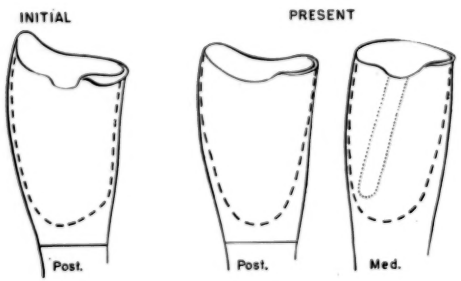

FIG. 4

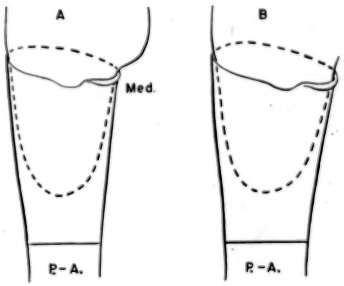

FIG. 5

Fig. 3: View of the suction socket seen from the top: *a*, ischial seat; *b*, cut-out for gluteal muscles; *c*, projection behind trochanter; *d*, cut-out for abductor muscles; *e*, valve opening. The anterior undercut is also shown.

Fig. 4: Drawing on the left illustrates the high lateral prolongation, deep gluteal cut-out, prominent ischial seat, and uniform snug fit of the early model suction socket. Posterior view is shown. The two figures on the right illustrate present model with snug fit only at the top, contact anteriorly, small medially placed ischial seat. Posterior and medial views are shown.

Fig. 5: *A* shows adductor roll. *B* shows adductor roll pulled down into the bucket.

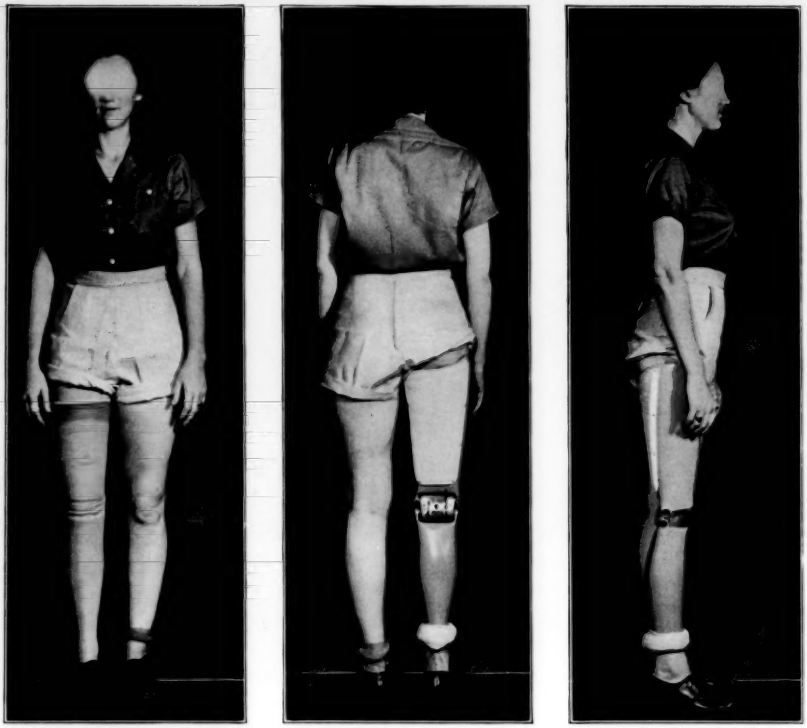

FIG. 6-A FIG. 6-B FIG. 6-C

Anterior, posterior, and side views of a patient wearing a suction-socket prosthesis are shown.

and the anterior surface of the stump. Elsewhere there is no contact between socket and stump. The Germans have recommended this type of socket.[3] It has been found, further, in those patients with an adductor roll, that this can be pulled down into the socket and made to disappear gradually (Fig. 5); thereafter patients are much more comfortable. It is worthy of comment that the shape of the top of the socket does not seem too important. In Group I there were eighteen with rectangular tops, seventeen with triangular tops, and seven with rather circular tops; the remainder were variations of these.

Significant factors in the shape of the socket appear to be that:

1. More pressure can be tolerated anteriorly at the top than was formerly thought possible;
2. The actual area of close contact between skin and socket needs to be only about two to three inches at the top;
3. There must be sufficient room about the distal end of the stump to prevent choking and oedema;
4. The ischial seat must be directly under the tuberosity;
5. The necessity for an accurate fit remains paramount.

Changes in the Stump

In the early suction-socket wearers, it was anticipated that an initial shrinkage in the circumference of the stump would occur and that this would be followed by hypertrophy. In this series of cases, however, except in those patients where there was a general

FIG. 7-A FIG. 7-B

Fig. 7-A: A patient is shown wearing a suction-socket prosthesis as he ascends a ladder. This patient built his own house.
Fig. 7-B: The patient shown in Figure 7-A is here shown jumping from a ladder.

weight loss, the shrinkage occurred in few instances. There were, however, rather marked stump changes which consisted for the most part in an increased circumference and in a disappearance of an adductor roll. It should be noted that the necessity for a second and third socket in several instances was due to the increasing size of the stump as the muscles developed. The muscle hypertrophy was sometimes accompanied by an increased firmness of the skin and subcutaneous tissue. The maximum increase in the circumference of the stump was five inches.

Valve

Considerable variation of opinion exists as to the most desirable type of valve. A springless valve, which is in effect a flap valve, is now being used extensively in the Los Angeles Veterans Administration Clinic. It permits automatic expulsion of air on standing, which makes positive pressure practically zero; it closes during the swing phase of the gait, building up to an estimated negative pressure of between one-half pound and one pound; it remains open when the patient is seated or reclining, permitting a partial exchange of air within the socket. This lessens the problem of perspiration.

Plastic Sockets

Only three of the original ten plastic socket wearers persisted in its use,—each of them has had three or more. We believe that the plastic socket is suitable only after the shape and size of the stump have become stable, for this plastic material does not lend itself to modification as does willow wood. When the stump has been stabilized, however, it makes a satisfactory socket. The difference in weight between the plastic socket and the willow-wood socket is slight.

Plug Fit

There are several plug-fit sockets in Group II, including that worn by one woman. It

would seem, as already explained, that this type of socket is undesirable, but these patients appear to be successfully fitted and satisfied. They would probably be more satisfactorily fitted, however, in an ischium-bearing socket.

SPECIAL GROUPS OF PATIENTS

Women

There were eight women in this series (Figs. 6-A, 6-B, and 6-C). Five were better satisfied with the suction-socket prosthesis than with the conventional prosthesis, while three were not successfully fitted. They appreciated particularly the following advantages of this type of socket:

1. A feeling of greater cleanliness and the lack of bulges under their clothing caused by the pelvic belt.
2. One, who went through pregnancy, stated that she would not have done so with a conventional prosthesis and its pelvic belt.
3. They are able to put the prosthesis on without removing their outer clothing.

They preferred the lateral motion ankle as they could walk better with it when wearing high-heeled shoes.

Children

There was one eleven-year-old girl in Group II. She has been a satisfactorily fitted wearer for ten months. The experience of other clinics in fitting children has been encouraging. Children are, of course, most adaptable; they have a good sense of balance, no inhibitions, and are anxious to walk.

Frantz, of Grand Rapids, Michigan, has treated fifteen children with suction sockets, two of whom were bilateral amputees. Sofield, of Chicago, has had four children in suction sockets.

The problem of replacement of a suction socket during the growth period is similar to that with a conventional prosthesis.

Bilateral Amputees

Experience with bilateral amputees wearing suction sockets in the Los Angeles Veterans Administration Clinic is limited to three patients, two of whom died of intercurrent diseases before they became good walkers. The one patient now under observation has been wearing two suction sockets for three months. He is a good walker, but he has not been followed long enough to be included in this series.

Thomas, of Denver, has had four bilateral amputees successfully wearing suction-socket prostheses.

Bechtol [2], of Oakland, states that he has had two successful wearers in his Clinic.

Lawrence, of New York, reported three seen in his Clinic. He suggests the addition of a Silesian band over the trochanter for these patients as an aid to beginning ambulation.

Daniel, in his monograph on the Rehabilitation Clinic at Bellevue Hospital, states that four bilateral amputees have been successfully fitted there.

The most troublesome factor in fitting bilateral amputees is the absence of one stable extremity to stand on while inserting the other leg into the prosthesis. While sitting, these patients have to put the stumps into the sockets either all the way, or far enough to stand and balance themselves while completing the bilateral application.

Unsuccessful Wearers

There have been, in this area, a number of unsuccessful suction-socket wearers. In almost every case, the patient, for one or another reason, did not persevere in his efforts to secure a satisfactory fit. In some instances, this was due to the personality of the pa-

tient; in others, where an initial satisfactory fit was not obtained, the patient simply became disgusted and refused further cooperation. Eleven patients in Group I, who started on the program, were either unable or unwilling to devote the necessary time and effort to obtain a satisfactory fitting. Others in the remaining groups were unsuccessful for various reasons.

Thorndike [13, 14], has stated that when the Veterans Administration program commenced, surgeons and the limb fitters were not too expert in making the suction socket. As experience was gained, however, less difficulty in fitting occurred, fewer modifications of the socket were necessary, less time was required of the patient, and fewer sockets had to be constructed. More difficulties were encountered in Group II and Group III, where supervision by the doctor and compulsory follow-up visits were usually lacking.

It should be emphasized that the Veterans Administration-National Research Council program has been successful because of the careful selection of patients and adequate follow-up visits (Figs. 7-A and 7-B). The success of the Veterans Administration Clinic has been dependent upon the complete cooperation of all people involved,—namely, the patients, the personnel in the Prosthetic and Sensory Aids Service of the Veterans Administration Regional Office, the limb fitters, physical therapists, and the doctors. The fitters in our area have faithfully attended the meetings of the Clinic, have accepted constructive criticism of their own work, and have made suggestions when called upon.

SUMMARY

A critical evaluation of 124 suction-socket prosthesis wearers who have been observed between six and fifty-five months, clearly indicates the desirability of this appliance.

Accurate fitting is an absolute necessity. Sufficient room at the lower end of the socket, and the placing of the ischial seat beneath the tuberosity are essential considerations. Some modification of the socket is usually required.

The number of patients who were unsuccessful suction-socket wearers for individual reasons does not detract from the practicability of employing this type of prosthesis in the majority of above-the-knee amputees.

The experience accumulated in the Los Angeles Veterans Administration Clinic indicates that, in the majority of cases, the above-the-knee amputee can, if adequate care is exercised, be fitted with a suction socket with a gratifying result.

The fitting of a suction-socket appliance requires even greater cooperation and investment of time by the patient, surgeon, and limb fitter than is demanded in the fitting of a conventional prosthesis.

In many individuals, hypertrophy of the muscles of the stump occurs, for these muscles are used to activate the prosthesis. The increase of stump circumference occasioned thereby may necessitate the construction of more than one socket before a final satisfactory fit is obtained.

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DISCUSSION

Dr. Augustus Thorndike, Boston, Massachusetts: In discussing this excellent paper, I shall limit my remarks to the authors' patients in Group I. Experience has shown that, in the past, we have judged and classified the above-the-knee amputee as a successful wearer of a suction-socket prosthesis too early. In a series of 221 patients which I reported in June 1949, only 4 per cent. of the patients were classified as failures, whereas when this same series was re-appraised one year later, 17 per cent. were actually classified as failures. It is our opinion that one should not appraise the final result until the suction-socket wearer has worn his prosthesis for at least twelve months or until he has had an opportunity to use it through all four seasons and in all climatic conditions. Excessive humidity, with the complication of sweating, has caused some of our successful wearers to abandon this type of prosthesis.

In reporting our series of 606 patients in the Veterans Administration Experimental Program in June 1950, we gave the failures as 13 per cent. This seems to me to be the probable incidence one might expect. However, with experience being gained by the limb fitters, in cooperation with our thirty Orthopaedic and Prosthetic Appliance Clinic Teams, we will lower this incidence of failure. Only last week, I had occasion to discuss with one of our consultants his experience in a recent follow-up of his thirteen failures originally reported. I was informed that he had since successfully fitted all but one,—a psychological problem. However, before accepting these twelve as successful, I advised him to follow them for another twelve months.

An appraisal of the types of valves has revealed that different types of valves are suitable for certain individual cases. A one-way valve has proved most desirable; a flap valve works satisfactorily in some cases, whereas others desire the closed type of valve and describe the value of the sense of feel of the stump "riding on an air cushion". All valves, however, must be so set that the negative pressure on the swing phase of walking does not exceed one and one-half pounds per square inch and the positive pressure in the stance phase of walking does not exceed one and one-half pounds per square inch. It should not be forgotten, however, that our best walkers, using contact on the sidewalls of the socket by contracting their remaining thigh muscles, can hold the prosthesis on without any valve.

A few words on the shape of the suction socket. Patients have been successfully fitted with a conical socket,—a plug fit. However, we prefer the quadrilateral shape, similar to the frozen section of the thigh, allowing a cut-out and shaping for the adductus longus, the glutaeus minimus and the glutaeus maximus, and the greater trochanter. The ischial seat has been so modified now that it is no longer an angular shelf, but is rounded and somewhat sloping at its anterior margin. We like to think of it as the point where the patient obtains weight-bearing. As the author has indicated, this point must be accurately determined to "bear" on the ischial tuberosity itself. The use of the term "barrel" to describe the shape of the socket, I do not like. Rather one should describe the shape below the rim as "under-cut" to permit the muscles to expand or contract. It should always be remembered that the stump of a suction-socket prosthesis wearer is an active functioning stump and that the remaining muscles of the stump become hypertrophied with use.

I wish to express my appreciation to your Program Committee for inviting me to discuss this excellent paper and to compliment the authors on this report of 124 patients.

Dr. James McAteer, New York, N. Y.: Dr. Mazet has presented a statistical study of 124 suction-socket wearers. At the outset, I would like to add a word of caution on the pitfalls of a purely statistical appreciation, especially from a comparative viewpoint with so many diversified and concealed factors coming into play,—such as the selection of cases, material, training, and indeed, the very yardstick by which success or failure is determined.

The causes of failure at the New York Regional Office Clinic of the Veterans Administration were along the same lines as reported by Dr. Mazet. With the accumulated experience of surgeons and craftsmen, many of the early difficulties were overcome.

Although in principle the suction socket is accepted as a useful prosthesis and in a great many cases has been enthusiastically received, in a larger sense, this type of prosthesis is still regarded as in an experimental stage; for, as Dr. Alldredge said in 1946, "It is not altogether clear as to exactly why the suction socket does not enjoy more widespread use or why its use has been discontinued by so many at different times, in different countries". We are still searching for the right answer.

There is a wide discrepancy of opinion as to the proper construction of the so-called ischial seat, with some experts making a large bench-like seat way beyond the tubercle zone, while others give preference to a

(*Continued on page 649*)

COMPARISON OF VITAL CAPACITY IN NORMAL AND POLIOMYELITIC SUBJECTS *

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The fact that a third or more of the motoneuron population may be destroyed before neuromuscular dysfunction occurs at the clinical level [1] suggested that partial paralysis of respiratory muscles might occur without overt clinical signs. It was thought that states of subclinical partial paralysis might be revealed by measurements of the maximal functional capacity of the thoracic cage. Since 1846, when Hutchinson carried out the first scientific investigation of the vital capacity of man, numerous studies have been made concerning vital capacity as it relates to many conditions, such as heart disease, tuberculosis, and pleurisy. To date, little attention has been given to the vital-capacity measurements of poliomyelitic subjects who were not respirator cases or who had no overt intercostal or diaphragmatic paralysis.

This report is concerned with a comparative study of the vital capacity of 270 poliomyelitic subjects, ranging in age from five to forty-nine years; thirty-nine subjects from eight to twenty-five years of age with scoliosis due to etiologies other than poliomyelitis; and 648 normal control subjects, ranging in age from five to forty-three years. Both female and male subjects were employed in the study. Approximately 75 per cent. of the poliomyelitic subjects were observed in the Orthopaedic Clinic at the State University of Iowa Hospitals over a six-month period, as each patient returned for treatment or to be checked. The remaining 25 per cent. were school children observed on field trips. Poliomyelitic subjects were selected for study if poliomyelitis had occurred at any age; selection was not, therefore, confined to any period of occurrence. The range of occurrence of poliomyelitis was from one week to forty-three years, averaging eight years for males and nine years for females before the time vital capacities were measured. It was very difficult to reckon with the factor of time in the development of scoliosis, but the range was from one to twenty-one years with an average of six years for all patients.

METHOD

Vital capacity of each subject was measured on a standard Hutchinson type of spirometer. Three trials were made and the largest reading, corrected to body temperature of 37 degrees centigrade, was recorded as the vital capacity. In view of the fact that various workers have shown that vital capacity has a high correlation with body surface area, it was decided to determine the surface area of each subject tested. For this purpose height and weight were recorded at the time of testing. Shoes were removed and proper deductions were made for other clothing. The vital-capacity quotient was calculated in liters of vital capacity per square meter of body surface area. Surface area was calculated from a standard Boothby and Sandiford nomogram, based on the formula of Du Bois and Du Bois. In view of the fact that some poliomyelitic subjects were unable to stand long enough to permit measurement of the vital capacity in that position, it was necessary to compare the vital capacity in the sitting and standing positions. Therefore, ninety-one normal males and twelve normal females, twenty through thirty-five years of age, were tested both in sitting and standing positions, in random order. At the time of testing each poliomyelitic subject, a description of residual effects was recorded and distinction was care-

* Aided by a grant from the National Foundation for Infantile Paralysis, Inc., New York, N. Y.

TABLE I

VITAL-CAPACITY QUOTIENTS IN POLIOMYELITIC SUBJECTS TREATED IN RESPIRATORS

Sex	Age (*Years*)	Duration (*Years*)	Scoliosis	Vital-Capacity Quotient *	Deviation (*Per cent.*)
M.	7	2	Moderate	1.02	−38
M.	14	8	Severe	0.91	−64
M.	23	12	Severe	1.28	−52
M.	30	18	Severe	1.70	−36
F.	18	2	None	0.84	−59
F.	16	4	Severe	1.37	−33
F.	37	2	None	0.30	−85
F.	27	12	None	0.70	−66

* Liters per square meter of surface area.

fully noted between respirator and non-respirator cases, scoliotic and non-scoliotic cases. Further, the degree of scoliosis was recorded.

Inasmuch as the body surface area of the subjects in this study was calculated from data on weight and height, and the height of the subjects was measured in an erect position, it was thought that a false height might be recorded, since a curvature of the spine causes its shortening. In order to determine whether or not the shortening of the spine caused by the scoliosis was great enough to produce a significant change in the calculated body surface area and vital-capacity quotient, the difference between the length of the curved and theoretically straight spines was calculated for twenty scoliotic subjects. Calculations were made according to the following procedure: Two landmarks were drawn upon an anteroposterior roentgenogram of the spine with the subject in the standing position, one above and one below the deformity. The straight distance between these two points was recorded. In case of overhang, this measure was taken from the upper landmark to its projection over the horizontal line that passed by the lower landmark. The true length of the spine between the landmarks was determined with the aid of a map meter. The difference between the length of the spine segment measured by the map meter and that measured by a straight line represented the increase in length of the spine if it had possessed a straight alignment. That figure, added to the apparent height of the subject, will give the true height.

RESULTS

The fact that values for vital-capacity quotients have been shown to vary with age and sex made it necessary to analyze statistically our results on the basis of age and sex groups. No significant difference was found between vital-capacity quotients of adult male and female subjects in the sitting and standing positions. Further, the average values found for the vital-capacity quotients of normal adult female and male subjects were almost identical with those reported by West.

It was found that the loss of height in a scoliotic patient as a result of the lateral curvature of the spine does not produce enough change in the calculated body surface to cause significant changes in the calculated vital-capacity quotient. In the authors' studies on twenty cases with different kinds and degrees of scoliosis, including double curves, the greatest difference between the apparent and the theoretically true length of the spine was eleven centimeters. The difference between the two lengths of the spine, the apparent and the true length, increases with the degree of deformity. Curves up to 105 degrees are included in this group of twenty cases. These differences in length produced only insignificant variations in the vital-capacity quotients and for the most part may be disregarded, since the largest difference found among the quotients was 0.06 liter per square meter of surface area, which represents a deviation of less than 4 per cent.

TABLE II

AVERAGE VALUES TOGETHER WITH STANDARD DEVIATIONS FOR THE VITAL-CAPACITY QUOTIENTS OF NORMAL AND POLIOMYELITIC SUBJECTS

Group (*Years*)	No. of Cases		Mean Vital-Capacity Quotients (Liters of Vital Capacity per Surface Area in Meters)			
	Normal	Poliomyelitic	Normal	Poliomyelitic	t Values †	Significant Level (*Per cent.*)
Females without Scoliosis						
5 to 6	25	7	1.40 ± 0.36	1.32 ± 0.16	0.552	60
7 to 8	20	6	1.59 ± 0.18	1.75 ± 0.13	2.078	5
9 to 10	22	9	1.68 ± 0.17	1.84 ± 0.34	1.684	20
11 to 12	31	14	1.82 ± 0.22	1.87 ± 0.17	0.735	50
13 to 17	75	27	2.03 ± 0.24	2.06 ± 0.28	0.526	60
18 and above	130	20	2.05 ± 0.20	2.06 ± 0.26	0.196	90
Females with Scoliosis						
5 to 6	25	0	1.40 ± 0.36			
7 to 8	20	5	1.59 ± 0.18	1.92 ± 0.14	2.713	2
9 to 10	22	5	1.68 ± 0.17	1.80 ± 0.26	0.865	40
11 to 12	31	3	1.82 ± 0.22	1.59 ± 0.47	1.465	20
13 to 17	75	13	2.03 ± 0.24	1.86 ± 0.33	1.379	20
18 and above	130	7a *	2.05 ± 0.20	2.19 ± 0.16	1.818	10
		7b **	2.05 ± 0.20	1.45 ± 0.20	7.595	0.1
Males without Scoliosis						
5 to 7	36	13	1.64 ± 0.22	1.55 ± 0.28	1.154	30
8 to 9	33	14	1.78 ± 0.24	1.90 ± 0.25	1.519	20
10 to 11	23	12	1.96 ± 0.15	1.97 ± 0.28	0.133	90
12	17	7	2.03 ± 0.17	1.88 ± 0.16	1.899	10
13	22	6	2.15 ± 0.30	2.22 ± 0.07	0.547	60
14 to 15	45	10	2.36 ± 0.21	2.41 ± 0.18	0.694	50
16	21	7	2.47 ± 0.21	2.61 ± 0.24	1.429	20
17 and above	148	20	2.64 ± 0.31	2.64 ± 0.28	0.000	100
Males with Scoliosis						
5 to 7	36	6a *	1.64 ± 0.22	1.70 ± 0.14	0.000	100
		6b **	1.64 ± 0.22	1.51 ± 0.10	1.398	20
8 to 9	33	4	1.78 ± 0.24	1.83 ± 0.03	0.403	70
10 to 11	23	6	1.96 ± 0.15	1.87 ± 0.22	0.485	70
12	17	4	2.03 ± 0.17	2.13 ± 0.31	0.840	50
13	22	5	2.15 ± 0.30	1.95 ± 0.70	1.591	20
14 to 15	45	4	2.36 ± 0.21	2.37 ± 0.17	0.091	90
16	21	3	2.47 ± 0.21	2.55 ± 0.44	0.497	70
17 and above	148	3a *	2.64 ± 0.31	3.13 ± 0.17	2.707	20
		7b **	2.64 ± 0.31	2.39 ± 0.61	1.953	10

* Slight scoliosis. ** Severe scoliosis.

† Level of significance is derived from a statistical analysis of data involving the factor "t". It expresses the probability of observed differences being due to chance; and the lower the level, the higher the reliability of the results.

The vital-capacity quotients (Table I) of eight subjects with partial paralysis of their respiratory muscles and with a history of having been treated in respirators were all significantly lower than those for normal controls for their age and sex.

The results of the study, which are summarized in Table II, show that there was no

TABLE III

AVERAGE VALUES FOR VITAL-CAPACITY QUOTIENTS OF NON-POLIOMYELITIC SCOLIOTIC SUBJECTS

Pattern	No. of Cases	Age (*Years*)	Deviation of Vital-Capacity Quotient (*Per cent.*)
Lumbar and thoracolumbar	9	15 (11 to 19)	−7 * (−18 to +16)
Thoracic or double curve with less than 45 degrees of deformity	14	14 (8 to 25)	−0.5 * (−23 to +25)
Thoracic or double curve with more than 45 degrees of deformity	16	15 (11 to 25)	−30 ** (−4 to −73)

* Not statistically significant. ** Statistically significant.

significant difference in the vital-capacity quotient in any age group between normal and non-scoliotic poliomyelitic female or male subjects. In general, there was no significant difference in the vital capacity between normal and scoliotic poliomyelitic male subjects. In general, there was no significant difference in the vital capacity between normal and scoliotic poliomyelitic female subjects. An exception is noted in the severely scoliotic female group eighteen years and older, where the mean vital-capacity quotient was significantly less than normal. In these groups, subjects were not included who gave a history of respiratory paralysis that required respirator treatment during the acute phase of the disease.

The vital-capacity quotients of subjects with non-poliomyelitic thoracolumbar or primary lumbar scoliosis were not significantly lower than those of normal controls for the same age and sex (Table III). Likewise, no significant difference was found between the vital-capacity quotients of subjects with non-poliomyelitic scoliosis with primary thoracic and primary double patterns, whose angle of deformity was less than 45 degrees, and of normal control subjects of the same age and sex (Table III). However, when the angle of deformity exceeded 45 degrees, a significant reduction in vital-capacity quotient was usually found. In a series of sixteen cases, the average values recorded in Table III show vital-capacity quotients 30 per cent. lower than those found in normal controls of the same age and sex.

Vital-capacity measurements involve the carrying out of a coordinated pattern of movement through a maximum range of motion, but do not necessarily reveal the maximum strength of the muscle groups involved. Although a majority of the patients exhibited considerable amounts of residual crippling, there was no significant difference between the vital-capacity quotients of normal and poliomyelitic subjects. These findings may mean either that the motoneuron pool of the respiratory muscles had suffered less permanent damage from the virus than the motoneurons supplying other muscle groups, or that more adequate compensation had taken place. The fact that subjects with respiratory involvement sufficient to require the use of a respirator during the acute phase of the disease exhibited low vital-capacity quotients indicates that there are limitations to compensatory adjustments.

The extent, if any, to which the infrequency of the occurrence of functional impairment in the respiratory neuromuscular apparatus can be attributed to the persistence of rhythmical activity throughout the periods of acute illness and convalescence is problematical. Only speculation can be advanced as to whether comparable activity in non-respiratory muscle groups would serve to lessen the functional impairment resulting from paralysis and spasticity. It might be of some interest to study the vital capacity of poliomyelitic patients at the end of the period of acute illness and at regular intervals for some time thereafter.

SUMMARY AND CONCLUSIONS

1. No significant difference was found in the vital-capacity quotients of subjects in the sitting and in the standing position.

2. The loss of height that might be present in a scoliotic patient as the result of the lateral curvature of the spine does not produce enough change in the calculated body surface area of that patient to cause significant changes in the vital-capacity quotient.

3. Subjects with extensive respiratory-muscle paralysis and with a history of having been treated in respirators exhibited vital-capacity quotients significantly lower than those found in normal controls for their age and sex.

4. There was no significant difference in the vital-capacity quotients between normal and non-scoliotic, non-respiratory poliomyelitic male and female subjects.

5. There was no significant difference in the vital-capacity quotients between normal and poliomyelitic scoliotic subjects when the degree of deformity was slight or moderate. However, in severe scoliosis an appreciable reduction in vital-capacity quotients was observed.

6. Non-poliomyelitic scoliotic subjects with either thoracolumbar, primary lumbar, primary thoracic, or primary double curve patterns with angular deformities of less than 45 degrees were found to have vital-capacity quotients which were within normal limits. A significant reduction in vital capacity was found in subjects with the thoracic pattern when the angular deformity exceeded 45 degrees.

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DISCUSSION

Cineplastic Muscle Motors

(*Continued from page 611*)

control, not the strength, to translate the muscular action to the keyboard. A single muscle motor made in the forearm permitted us to translate that action into a hook and hand—hooks for action and a hand for appearance—to enable him to carry out the routine pursuits of life. Although the excursion of the muscle motor is rather small, his control is extraordinarily good.

The hands and hooks given him are not of the conventional type; they are spring-operated with a toggle mechanism. Both hooks and hands can be interchangeably operated without a great deal of power or strength but with simple neuromuscular control. There are very few amputees, particularly arm amputees, who wish or expect to become pianists. This man had a great deal of emotional background, interest, and determination; and, after being provided with the necessary devices, he was able to proceed with his piano playing.

Col. August W. Spittler (closing): I want to thank both of the discussors. I realize there are many other muscles that can be activated and cinetized for various controls. Representatives of International Business Machines have discussed with me the possibility of muscle motors to control the switches on their electric arms. We have kept this program as simple as possible, realizing that the soldiers are going to be leaving us some day. I believe that at the present time they can be fitted and have their limbs fixed in any part of the country. I want to re-emphasize before this work is received with too much enthusiasm that "the team" has to be there before the tunnel is made—the patient, doctor, and limb fitter all have to know where the patient is going and what he will do. It has to be a continuous program.

LOW-BACK AND SCIATIC PAIN

Results of Treatment *

BY JOSEPH S. BARR, M.D., BOSTON, MASSACHUSETTS

Pain — "a form of consciousness characterized by desire of escape or avoidance".—*Webster*

The conscious individual human being is in a large measure occupied by the pursuit of pleasure or the avoidance of pain. Philosophers, psychologists, physiologists, and physicians—ordinary and extraordinary—have contributed to our knowledge of the nature of pain. Much remains to be discovered, but it is well to review briefly some of the pertinent points concerning the origin and nature of pain in general, and of the special variety called low-back and sciatic pain, before discussing treatment.

The form of consciousness known as low-back and sciatic pain is felt (projected or referred) by the patient in certain ill-defined anatomical portions of the back and lower extremity. The patient usually assumes that the pain actually resides in those areas and may refuse to believe that the perception of pain is a function of the higher cerebral centers. The impulses which are interpreted as painful are conducted by specialized unmyelinated, fine nerve fibers which have unencapsulated "free nerve endings" in the skin, deep somatic, and visceral structures. They are quite distinct from the nerves concerned with touch and temperature. The neurons concerned with conduction of pain, in common with other sensory neurons, have their cell nuclei in the dorsal root ganglia. Each sensory nerve root has a specific pattern of distribution to the skin and to the muscles, tendons, ligaments, joints, and viscera. Noxious stimuli applied to any of these structures will produce painful sensations. Pain sense is a protective mechanism, and its threshold is at the approximate level of threatened tissue damage. A painful stimulus applied to the skin is accurately and easily localized, but pain impulses arising in deeper somatic structures are poorly localized, poorly differentiated, and the sensation is often projected to uninvolved skin

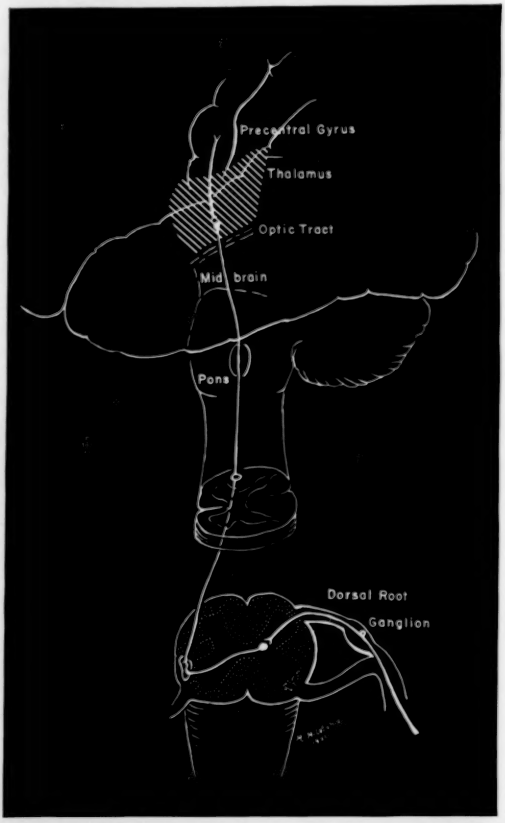

Fig. 1

* Presented at the Fifth Congress of the International Society of Orthopaedic and Traumatic Surgery, Stockholm, Sweden, May 21, 1951.

TABLE I

LUMBO-SACRAL PLEXUS

SPINAL ROOT—NERVE—MUSCLE CHART *

Root					Nerve	Muscle
L3	L4	L5	S1	S2		
						Spinal Muscles
+	+	+			Dorsal rami	Intertransversarii
+	+	+	+	+	Dorsal rami	Longissimus
+	+	+			Dorsal rami	Multifidus
+	+	+			Dorsal rami	Rotatores
+	+	+			Dorsal rami	Interspinales
+	+				Ventral ramus	Quadratus lumborum
						Muscles of the Lower Extremities
+	+				Femoral	Iliacus
+	+				Femoral	Quadriceps femoris
+	+				Obturator	Adductor brevis
+	+				Obturator	Obturator externus
+	+				Obturator	Adductor magnus
	+	+	+		Ventral ramus	Quadratus femoris
	+	+	+		Ventral ramus	Gemellus inferior
	+	+	+		Superior gluteal	Glutaeus medius
	+	+	+		Superior gluteal	Glutaeus minimus
	+	+	+		Superior gluteal	Tensor fasciae latae
	+	+			Peroneal (deep)	Tibialis anterior
	+	+	+		Peroneal (deep)	Extensor hallucis longus
	+	+	+		Peroneal (deep)	Extensor digitorum longus
	+	+	+		Peroneal (deep)	Extensor digitorum brevis
	+	+	+		Peroneal (deep)	Peronaeus tertius
	+	+	+		Peroneal (superficial)	Peronaeus longus
	+	+	+		Peroneal (superficial)	Peronaeus brevis
	+	+	+		Tibial	Plantaris
	+	+	+		Tibial	Popliteus
	+	+	+		Medial plantar (tibial)	Lumbrical (first)
	+	+	+		Medial plantar (tibial)	Abductor hallucis
	+	+	+		Medial plantar (tibial)	Flexor hallucis brevis
	+	+	+		Medial plantar (tibial)	Flexor digitorum brevis
		+	+	+	Inferior gluteal	Glutaeus maximus
		+	+	+	Sciatic (com. peroneal)	Biceps
		+	+	+	Sciatic (tibial)	Semitendinosus
		+	+	+	Sciatic (tibial)	Semimembranosus
		+	+	+	Tibial	Flexor hallucis longus
		+	+		Tibial	Flexor digitorum longus
		+	+	+	Tibial	Soleus
		+	+		Tibial	Tibialis posterior
			+	+	Ventral ramus	Obturator internus
			+	+	Ventral ramus	Gemellus superior
			+	+	Ventral ramus	Piriformis
			+	+	Tibial	Gastrocnemius
			+	+	Lateral plantar (tibial)	Adductor hallucis
			+	+	Lateral plantar	Abductor digiti quinti
			+	+	Lateral plantar	Flexor digiti quinti brevis
			+	+	Lateral plantar	Quadratus plantae
			+	+	Lateral plantar	Interossei

* Adapted from Favill's *Outline of the Spinal Nerves*. Springfield, Illinois, Charles C. Thomas, 1946.

areas supplied by the same nerve root. An accurate knowledge of the somatic and visceral distribution of each nerve root is invaluable in the diagnostic search for the origin of

painful stimuli. On entering the spinal cord, the "pain fibers" from all tissues, somatic and visceral, pass to the opposite side of the cord through an intermediate synapse and ascend the cord in the lateral spinothalamic tract to the thalamus and cerebral cortex (Fig. 1). At thalamocortical levels integration, selection, and interpretation of nerve impulses produce that form of consciousness called pain.

The major sensory components of the sciatic nerve arise from the first sacral and the fourth and fifth lumbar roots. They supply pain, touch, and temperature fibers to their respective skin areas (dermatomes) in a pattern familiar to all of us (Fig. 2). They supply fibers concerned with pain, position sense, and deep pressure to a large group of muscles and their tendons (Table I). They also send branches to the capsules and supporting ligaments of the small joints of the foot, the ankle, the knee, and the sacro-iliac joint. They also supply, via the recurrent nervus sinuvertebralis, the posterior joints and the annulus fibrosus of the lower lumbar intervertebral discs, and the adjacent intervertebral ligaments (interspinous, interlaminar, *et cetera*). It is of interest that these three nerve roots furnish few or no "pain fibers" to the abdominal and pelvic viscera.

Noxious stimuli applied to any of the structures mentioned above will excite "pain fibers" which produce painful sensations. Table II lists some of the stimuli effective in producing pain sensation in various tissues.

Direct stimulation of the nerve endings in somatic or visceral structures is only one of the pain-exciting mechanisms. Noxious stimuli applied to a nerve trunk produce a sensation of severe pain, not well localized, referred usually to areas distal to the lesion, but often extending proximally also. Pressure on the sciatic nerve—for example, sitting on a narrow board—produces tingling, numbness, and pain referred down the extremity in a very diffuse fashion.

In a search for possible causes of sciatica, vulnerable areas in the lower extremity

FIG. 2

FIG. 3

should be carefully checked for nerve pressure,—such as the metatarsal-phalangeal joints of the foot (plantar digital neuroma), the region of the internal malleolus, the neck of the fibula (osteochondroma), the popliteal space (bursa or cyst), and the sacrosciatic notch (Fig. 3). Proximal to this point, clinical examination of the nerve trunk and roots becomes impossible, except for a short segment palpable on rectal or vaginal examination. In the pelvis, the lumbosacral plexus passes close to the anterior aspect of the sacro-iliac joint and may be irritated by an exudative or inflammatory process, such as tuberculosis or acute rheumatoid arthritis involving this joint.

The fourth and fifth lumbar nerve roots enter the spinal canal through foramina which are narrowly circumscribed by the intervertebral disc and adjacent vertebral bodies, the articular facet, capsule, and the adjacent pedicles of the vertebrae. The first sacral root crosses the lateral aspect of the lumbosacral interspace obliquely as it courses toward its sacral foramen lying between the fifth lumbar disc anteriorly and the facet posteriorly.

Anatomical investigations have demonstrated that the dural sac enveloping the cauda equina is inelastic and relatively fixed. The lower lumbar nerve roots as they emerge from the theca are covered by a prolongation of the dural sheath and have little mobility in the intraspinal portion of their course. When the knee is extended and the thigh is flexed (straight-leg-raising test), the lumbosacral roots, particularly the first sacral, are drawn distally and are put under tension. This firmly fixes the root ventrally against the adjacent disc and allows no opportunity of its escaping pressure from a posterior disc protrusion. Articular facet changes due to injury, infection, or degenerative processes may also affect the adjacent nerve root.

Spondylolisthesis and spondylolysis may produce root pressure and radiating pain through several distinct mechanisms: (a) Direct pressure on the *posterior* surface of the root may occur in the region of the defective articular facet; (b) a concomitant disc protrusion may cause root pressure on its anterior aspect; (c) the roots in some cases of spondylolisthesis may be stretched in their long axes.

But clinical experience has shown that disc lesions far outnumber all other causes of low-back and sciatic pain.

In its intradural course the nerve root may be involved by chronic arachnoiditis or by a tumor, such as a neurofibroma. In rare instances localized lesions of the conus medullaris or the lateral spinothalamic tract may also give rise to low-back and sciatic symptoms.

The painful afferent impulses from noxious stimuli give rise to reflex efferent impulses which are motor-stimulating; this may result in muscle spasm which stimulates the deep "pain fibers". So a vicious cycle of pain, muscle spasm, and increased pain is set up and the phenomenon of primary stimulation with reflex augmentation is established.

At the cortico-thalamic level, all of the sensory impulses including those carried by "pain fibers" are received, integrated, and interpreted. Here we invade the fields of psychology and psychiatry and substitute for anatomical neurophysiology and pathological

TABLE II

EFFECTIVE STIMULI FOR THE PRODUCTION OF PAIN SENSATION IN VARIOUS TISSUES

Tissue	Stimulus (approximating the amount which produces tissue damage)
Skin	*Mechanical*—pin prick, pinch, crush *Thermal*—excessive heat or cold *Chemical*—acid, etc. *Electrical*
Muscle	*Mechanical*—firm, massive pressure, sprain *Ischaemia*—cramp, spasm, anoxia *Chemical*—hypertonic saline
Fascia and Tendon	*Mechanical*—pressure, sprain, strain *Chemical*—hypertonic saline, calcium deposit
Ligament	*Mechanical*—strain, sprain *Chemical*—hypertonic saline, calcium deposit
Joint	*Mechanical*—massive effusion (stretch) *Chemical*—gout
Bone	Periosteum—stretch, infection, tumor, osteoid osteoma
Viscus	Stretch
Nerve trunk	*Mechanical*—pinch, stretch, tumor *Electrical* *Chemical*

terminology such concepts as types of consciousness, perception of sensation, and their repression or augmentation. We know that fear, anxiety, and preoccupation are potent in augmenting pain. Good physician-patient relationship allays fear and so decreases pain. The inept physician can multiply fears and may contribute to the production of an ineradicable psychic overlay. The psychosomatic problems of low-back pain are fascinating and poorly understood. Neurosis, such as hysteria, and depression may translate loss of economic security into a powerful augmentation of the pain from a relatively trivial muscle strain.

We must not lose sight of the fact that the irreducible unit of treatment is the individual and that we treat patients, not diseases. We, therefore, strive to know what kind of disease the patient has, and also what kind of patient has the disease.

A formidable list of potential causes of low-back and sciatic pain can be drawn up (Table III). Modern concepts of disease suggest that there are multiple important factors in each individual case. Rarely should we be trapped into accepting the concept of a single "cause" producing a circumscribed "effect". That narrow viewpoint is the trademark of the cultist. For example, certain surgeons with fanatic ardor seem to believe that a painful back and sciatica are synonymous with a protruded disc and that immediate surgical excision is the equivalent of cure. There are too many such cultists, and each has on his tally sheet a not inconsiderable number of therapeutic disasters which, with care, might have been avoided. Those who have studied the problem of low-back and sciatic pain recognize that disc lesions *frequently* produce root pressure and sciatic pain. The lesion may be traumatic in origin, representing normal displaced disc tissue, but much more frequently it is *degenerated* disc tissue which is displaced. Often degeneration plus trauma (acute or physiological) are coincident factors. The size of a particular disc lesion may vary, increasing because of additional protrusion or decreasing from a process of dehydration. A free fragment of protruded disc tissue may change its location by migration, thus occasionally relieving root pressure.

The local pathological condition of the affected nerve root is also subject to change. The factors of inflammatory reaction are present in variable amounts and of variable duration,—as oedema, blood-vessel engorgement, cellular infiltration, and intraneural or perineural fibrosis. Individual nerve fibers which have been affected by a disc lesion may recover completely, or they may undergo axonal degeneration with loss of ability to respond to stimuli.

TABLE III

ETIOLOGICAL CLASSIFICATION OF CAUSES OF LOW-BACK AND SCIATIC PAIN *

Systemic Disease:
- Small-pox prodrome
- Many fevers, acute
- Typhoid
- Tuberculosis
- Syphilis:
  - Pachymeningitis
  - Tabes
  - Gumma
- Myositis
- Neuritis
- Von Recklinghausen's
- Meningitis
- Malignancy
- Guillain-Barré

Local Neoplasm
- Uterus
- Ovary
- Rectum
- Prostate
- Extramedullary
- Conus and cauda
- Neuroma
- Vertebral, benign:
  - Osteoma
  - Osteochondroma
  - Giant-cell
- Vertebral, malignant:
  - Metastatic (from prostate, breast, etc.)
  - Myeloma
  - Primary osteogenic sarcoma
  - Ewing's sarcoma
- Hemangioma or glomus

Local Inflammation, etc.
- Myelitis
- Hematomyelia
- Subarachnoid hemorrhage
- Arachnoiditis
- Epidural abscess
- Lipiodol residue
- Lumbar puncture
- Herpes zoster
- Salpingitis
- Prostatitis
- Retroperitoneal abscess
- Ligamentous relaxation due to pregnancy
- Hypertrophied ligamentum flavum
- Aneurysm of iliac artery

Muscle Spasm or Ischaemia from:
- Trauma, acute:
  - Fracture (pedicles, spondylolisthesis)
  - Dislocation
  - Sprain (sacro-iliac)
  - Laceration
  - Wounds
  - Disc compression or extrusion
  - Coccygodynia from spasm of:
    - Levator ani
    - Coccygeus
    - Piriformis

Trauma, Chronic, due to:
- Obesity
- Pregnancy
- Multiparity
- Occupation:
  - Mail carriers
  - Chauffeurs
  - Miners
- Foot pronation
- Contracted tensor fasciae latae
- Gluteal injections

Congenital Deformity (Seldom the real cause, but increases susceptibility)
- Spina bifida
- Meningocele
- Sacralization of fifth lumbar
- Lumbarization of first sacral
- Anomalous facets (spondylolisthesis)

Arthritis
- Atrophic or rheumatoid
  - Periarticular
  - Of small posterior joints
  - Sacro-iliac
  - Marie-Strümpell type (spondylitis ankylopoietica)
- Hypertrophic or osteo-arthritis
  - Sacro-iliac (in aged)
  - (Lipping, probably not a cause of pain)
- Gout

* Adapted from Favill's *Outline of the Spinal Nerves*. Springfield, Illinois, Charles C. Thomas, 1946.

Low-back and sciatic pain is a most heterogeneous and complex subject. Many musculoskeletal structures, endowed with limited functional capacities, must meet the stress and strains of physical activities. There is a large and complex neural component anatomically in close approximation to vulnerable skeletal structures. In many instances, the combination of low-back and sciatic pain suggests the presence of a combination of associated "causative" factors. There may be *local* pain due to excessive stress on local somatic structures. The sciatica may be due to associate root pressure. When *radiating pain* is the dominant symptom, direct root or nerve involvement is usually present. The theory of reflex reference of pain need not be invoked as frequently today as it was before we were aware of disc lesions.

The pathological processes involved are intricate and vary continuously. Each patient interprets, augments or diminishes, and reacts to the painful impulses initiated by them in his own individual fashion.

The physician who refuses to make a "snap" diagnosis and who collects and interprets wisely all of the pertinent facts from history, physical examination, and laboratory tests will know his patient and will in many instances arrive at a satisfactory understanding of the problem.

Selection of proper treatment requires an accuracy of knowledge which we must confess is still in many instances beyond our professional abilities. Trial and error, empiric and pragmatic methods are common practice, and must in fact continue in use till more scientific data are available.

Treatment of Intervertebral-Disc Lesions

In the remaining time at my disposal, I would like to comment on some aspects of the treatment of intervertebral-disc lesions. Unfortunately, there are as yet no clinical methods by which we can accurately determine the exact nature and extent of the pathological changes present in individuals with low-back and sciatic pain due to intervertebral-disc lesions. The most careful analysis of signs, symptoms, and laboratory findings in an individual case scarcely allows one to hazard a prognosis. Various authors have studied the prognosis in medically treated sciatica. Allowing for variations in selection of cases, methods of treatment, and accuracy of evaluation, the results of various reported series are remarkably similar. Ytrehus reported 256 patients (60 per cent. males), representing 2 per cent. of the admissions to a general hospital, who had severe sciatic pain with a positive Lasègue's sign. No more accurate diagnostic classification was attempted. Obviously disc lesions, spondylolisthesis, spondylitis deformans, and other diagnostic entities were included. Treatment consisted in complete bed rest, local heat, and sedation. The average hospital stay was thirty-seven days; on discharge, 47 per cent. of the patients were free of symptoms, and most of the others were improved. Two to eight years later, 220 (86 per cent.) of the patients were re-evaluated; of these 34 per cent. were at full work without symptoms, 37 per cent. were at full work but had symptoms, and 29 per cent. were at least partially disabled. Thirty per cent. had recurrences severe enough to require sick leave or re-hospitalization. Boysen's results (431 cases) were in general similar to those of Ytrehus. She noted that after the age of forty-six relapse is rare. Colonna has carefully studied a group of patients who clinically and by myelogram had symptoms of an intervertebral-disc lesion. Following "conservative" treatment, 29 per cent. were found to be symptom-free at end-result study, while 71 per cent. had some residual disability, and 57 per cent. were intermittently completely disabled.

The size of the myelographic defect, if one is present, bears little relationship to the end result. We have noted instances of spontaneous recovery in which the myelographic defect has remained unchanged. *Most observers agree that about 30 per cent. of patients with disc lesions will recover spontaneously from their first attack*, and many of these will have no further symptoms for long periods of time. Those patients who have had two or more

recurrences are unlikely to have either prolonged or complete remissions and are faced with the choice between restriction of activities with partial invalidism and attempted relief by operative methods.

We may conclude that the variability of the clinical course in patients with disc lesions makes an analysis of results of treatment extremely difficult, and our statements must be tentative.

I. Conservative Treatment

Here we recognize certain important factors:

a. *Time lapse:* The pathological process must run its course, and miracle cures are not to be expected.

b. *Favorable influences:* The low-back structures should be protected from strain and irritation by such measures as bed rest, possibly supplemented by braces, corsets, strapping, plaster casts, *et cetera*. Additional measures may include sedation, application of heat, removal of psychic overstimulation from pain and fear. Traction and manipulation are of doubtful value.

c. *Unfavorable influences:* A large lesion causing severe root pressure, recurring trauma, excessive reflex muscle spasm, mechanical instability of the involved segments of the vertebral column, an accelerated degenerative process (rapid aging) of discs, articular facets, and contiguous ligamentous structures are factors which may prolong symptoms or prevent recovery under conservative treatment.

Ill-advised or improperly applied treatment, such as forcible manipulations or repeated nerve injections, may make the patient worse instead of better. Psychic trauma may also be inflicted by the physician who is inept. These may be called iatrogenic factors.

II. Operative Treatment

The greatest single advance in the treatment of sciatic pain has been the development of a simple, safe operative method of relieving nerve-root pressure by removing protruded disc tissue. Approximately 80 per cent. of patients with this syndrome are permanently relieved of acute pain and restored, at least partially, to satisfactory functional ability. Here is a therapeutic weapon of proved value, and it is our first thought when conservative measures fail to give satisfactory relief. Enthusiasm must be tempered with sound judgment, however, and it is wise to turn our attention to the problems and the potential dangers of operative treatment.

Causes of Failure in the Operative Treatment of Disc Lesions

1. Wrong diagnosis or incomplete diagnosis;
2. Delay in treatment;
3. Poor selection of cases;
4. Surgical risks and complications;
5. Poorly supervised after-care.

1. *Wrong diagnosis* needs little comment. Removal of an innocuous bit of disc tissue when there is present an intra-thecal neurofibroma will obviously fail to relieve symptoms. Myelography is of great value in arriving at an accurate diagnosis and we use it almost routinely. With proper technique, it is a relatively simple and safe procedure, of great localizing value, eliminating in many cases the need to explore two or more interspaces.

It is not commonly recognized that removal of an unequivocal disc lesion will fail to relieve the symptoms of the patient who also has a major mental component in the form of deep-seated fear, anxiety, and guilt feelings. Unfortunately, some surgeons on recognizing the presence of a psychic deviation from the norm exclude such patients from

TABLE IV

COMPARISON OF FIFTY DISC CASES FUSED AND FIFTY UNFUSED TREATED BY ONE SURGEON (Garceau)

Result	Combined Operation	Excision Only
Excellent	56 per cent.	64 per cent.
Fair	26 per cent.	23 per cent.
Poor	18 per cent.	13 per cent.
Of 27 Cases with Proved Solid Fusion, the Results were:		
Excellent	20	74 per cent.
Fair	6	22 per cent.
Poor	1	4 per cent.

the benefit of surgery. Recognition, frank discussion, and attempted correction of the psychic factors accompanied by properly-timed, adequate surgery will yield brilliant therapeutic results in many otherwise hopeless situations.

2. *Delay in treatment:* A poor result can be expected if root pressure has been so prolonged or severe that irreparable damage has been done. If there is root fibrosis and degeneration, with resultant motor weakness or paralysis and major sensory deficit, the changes will be irreversible and an unsatisfactory operative result is inevitable.

3. *Poor selection of cases:* Patients with widespread, rapidly progressive, degenerative disc disease are poor operative subjects and are usually best treated by conservative measures.

Patients with local mechanical changes—such as spondylolisthesis, spondylolysis, and subluxation of articular facets—may be relieved of their acute sciatic symtoms by disc excision, but continued pain and weakness of the back, unless corrected by stabilization of the affected segments, frequently lead to disappointing results.

4. *Risks and complications of surgical treatment:*

The mortality rate in disc surgery is very low (less than 1 per cent.). Adequate preoperative preparation, modern anaesthesia, replacement of blood loss, and sound surgical technique have reduced the operative mortality rate in good clinics to the vanishing point. Pulmonary embolism occurring one to four weeks postoperatively is still a tragic possibility and accounts for most of the deaths. Its recognition and treatment are beyond the scope of this paper.

Postoperative sepsis occurs rarely (in 4 per cent. or less in most reported series). Superficial sepsis may be of little importance, but deep-seated infection of the intervertebral space is serious and leads to prolonged disability. The intervertebral disc is essentially avascular, and symptoms of disc-space infection may develop slowly, manifested by *malaise, pyrexia, and painful spasm of the low-back musculature.* The white blood count and the sedimentation rate are usually moderately elevated. The earliest changes seen by x-ray are localized atrophy of the adjacent vertebral bodies and loss of cortical bone detail. There is late narrowing or collapse of the disc space with peripheral deposition of new bone. This finally results in osseous fusion of the adjacent vertebrae.

Treatment consists in general supportive measures, adequate chemotherapy (antibiotics), and splinting of the back by bed rest and a cast, corset, or brace. The prognosis for eventual recovery is good, although the symptoms may persist for many weeks or months. Surgical drainage of the infection is technically difficult and in most instances seems to be unnecessary.

Operative damage. The nerve roots in the spinal canal are shielded from visual inspection by a variety of structures, each with specialized function. The term "atraumatic" can scarcely be properly applied to any surgical approach which allows exposure of

TABLE V

INTERVERTEBRAL DISC LESIONS
COMPARATIVE END-RESULT STUDY OF 100 CASES *

	Excision and Fusion	*Excision*
Male	38	33
Female	12	17
Average age	33	35
Location of lesion		
Third lumbar	0	1
Fourth lumbar	24	19
Fifth lumbar	25	29
Double lesion (Fourth and fifth lumbar)	1	1
Side		
Right	20	21
Left	30	28
Bilateral	0	1
Average period of follow-up (*Years*)	8.6	8.1

* 50 cases Excision with Fusion, 50 cases Excision only } Massachusetts General Hospital 1941–1946.

a nerve root and the adjacent intervertebral disc. The elastic supraspinous, interspinous, and interlaminar ligaments are partially excised, later to be replaced by inelastic fibrous tissue. The small intervertebral joints are often opened, with sacrifice of part of their capsular ligaments and, not infrequently, in a careful search for a laterally placed disc protrusion, the facets themselves are partially removed. Thus, the anatomical integrity and function of the involved segment of the spinal column is probably impaired to some extent in every exploration. The conscientious surgeon is, therefore, constantly balancing his desire to see as much as possible against his certain knowledge that multiple interspace exploration, with replacement of normal structures by fibrous tissue, must decrease the functional capacity of the spine.

Fortunately *loss of motion* of one or two segments of the lumbar spine is of little practical significance and may result in no functional disability. However, local strain, in stability, fibrosis, and hypertrophic change may, in some cases, produce symptoms of back pain and weakness sufficient to force the patient to limit his physical activities. We have noted certain patients with postoperative recurrent low-back and sciatic pain, who on re-exploration were found to have excessive fibrous-tissue reaction with extensive adhesions involving nerve roots, dura, interlaminar and articular structures,—a veritable "internal keloid". This overproduction of scar tissue is usually seen in cases in which there had been partial or complete facetectomy during an extensive exploratory procedure at a previous operation. Perhaps this reaction represents nature's spontaneous inefficient attempt to stabilize the spine. Excision of the scar tissue, freeing of the nerve roots, and arthrodesis of the involved spinal segments has, in a few cases, resulted in permanent relief of symptoms.

TABLE VI

COMPARATIVE RESULTS, EARLY POSTOPERATIVE

	Excision and Fusion	*Excision*
Average Postoperative Hospital Stay (*Days*)	40	18
Complications		
Wound Infection (Cases)	3	4
Phlebothrombosis (Cases)	2	1
Return to Full Activity (*Months*)	7	4.3

Retraction of nerve roots during surgical exploration ordinarily causes no recognizable injury, but occasionally, even in skilled hands, sufficient damage occurs to produce motor weakness or paralysis with resultant foot-drop. The operative result in such cases, even though pain is relieved, can scarcely be classed as satisfactory.

Occasionally the operative result is unsatisfactory because the surgeon fails to completely remove the displaced disc tissue, or he fails to recognize multiple lesions occurring at more than one spinal level. Undue emphasis had been placed by some authors on the frequency of this latter occurrence. Double disc lesions are found by some surgeons in 20 per cent. of their cases. We suggest that they mistake anatomical variations, such as Schmorl's nodules, for pathological processes.

5. *Neglect of proper medical supervision* during the period of recovery from surgery undoubtedly helps to produce unsatisfactory results. Muscular weakness and postural defects should be corrected by a graduated, supervised program. Physical activities are increased systematically, but are kept within physiological limits of tolerance. Fears and phobias are recognized and dispelled with proper reassurance.

If surgical excision of protruded disc tissue is reserved for those who have a disc lesion and also have severe intractable sciatic pain, gratifying results can be confidently expected. The severe sciatic pain will be relieved in over 90 per cent. of the cases. In 5 to 10 per cent., the result will be classed as unsatisfactory and further surgery will be necessary for recurrent or unrelieved sciatic symptoms.

The result of disc excision, so far as back pain is concerned, is much less satisfactory. At least 50 per cent. of the patients complain of backache or weakness of the back. Waris noted in his operative series that the incidence of back pain was greater at end-result than it was before operation. A number of observers have commented on the fact that disc excision is not a satisfactory method of treating back pain, and that the operation should be reserved for patients with intractable sciatica.

Disc Degeneration and Instability of the Spine

During the past thirty years certain American orthopaedic surgeons have recognized that lumbar backache is often due to strain or mechanical instability and, in selected cases, have stabilized the spine by a fusion operation. Unquestionably some of these pa-

TABLE VII

END-RESULT STUDY OF SCIATIC SYMPTOMS

	Excision-Fusion		Excision	
	No. of Cases	*Per cent.*	*No. of Cases*	*Per cent.*
None	34	68	28	56
Mild	14	28	21	42
Moderate or Severe	2	4	1	2
Satisfactory		96		98

TABLE VIII

END-RESULT STUDY OF BACK SYMPTOMS

	Excision-Fusion		Excision	
	No. of Cases	*Per Cent.*	*No. of Cases*	*Per Cent.*
None	29	58	11	22
Mild	11	22	21	42
Moderate or Severe	10	20	18	36
Satisfactory		80		64

TABLE IX

ADDITIONAL OPERATIONS

	No. of Cases		No. of Cases
A. Excision-Fusion Cases		*B. Excision Cases*	
Re-explorations for disc recurrence	2	Re-exploration for disc recurrence	4
Excellent 1		Excellent 0	
Unsatisfactory 1		Good 2	
Repair of pseudarthrosis	5	Unsatisfactory 2	
Excellent 1		Fusion for back symptoms	5
Good 2		Excellent 2	
Unsatisfactory 2		Good 2	
		Unsatisfactory 1	
Total	7	Total	9

tients had an unrecognized, unremoved disc protrusion, and the operation failed to give relief. Nevertheless, spine fusion for the relief of "mechanical low-back pain" is a therapeutic method of proved value. Friberg, Hirsch, and others have made valuable contributions to our knowledge of the role of disc degeneration in the production of low-back pain. Disc degeneration occurs frequently; apparently it is an example of the normal aging process in collagen-bearing tissues. Loss of elasticity of the disc may be accompanied by disc narrowing, local vertebral hypertrophic change, subluxation of articular facets, retroposition of the superior vertebra, and abnormal mobility as demonstrated in bending films. Although in many cases disc degeneration is asymptomatic, in others it plays an undoubted etiological role in the production of back pain. In such cases, spine fusion of the involved vertebral segments is often successful in alleviating symptoms. It is a matter of common knowledge that in general a fused joint is a painless joint. Wahren, for instance, in a study of seventy-one patients who were incapacitated by low-back pain, due to disc degeneration without evidence of nerve-root pressure, reported 60 per cent. excellent or good results, and 40 per cent. fair or poor results following spine fusion.

Disc Excision and Spine Fusion

Although the operation of disc excision for sciatic pain has been practised in some clinics for almost twenty years, and has been universally accepted as a valuable therapeutic procedure for ten years, there is as yet no unequivocal answer to the question as to whether or not fusion should accompany disc excision.

In the United States, Caldwell, Spurling, and others are strong advocates of simple excision and recognize no indications for or benefits derived from the combined operation of excision-fusion. Caldwell and Sheppard conclude: "There are no criteria for spine fusion following removal of a protruded nucleus pulposus".

In other clinics the combined operation is performed in selected cases. At the Mayo Clinic, excision only was originally advocated by Love. A later report from that Clinic by Young and Walsh indicated that the combined operation had risen in popularity and in 1943–1944 was performed in 28 per cent. of the patients operated upon for disc lesions. Although they made no accurate statistical comparison, their figures suggested that the results of the combined operation were somewhat better than the results of disc excision only.

Garceau, reporting the comparative results in fifty cases with the combined operation and fifty cases with excision only, noted no statistical difference in the end results. It will be seen, however (Table IV), that his results in cases with solid fusion demonstrated by x-ray were superior to those with excision only.

At the Massachusetts General Hospital the combined operation of disc excision and spine fusion has been performed on selected cases since our first recognition of the disc

TABLE X

RESULT OF ORIGINAL OPERATION

	Excision-Fusion		Excision	
	No. of Cases	*Per cent.*	*No. of Cases*	*Per cent.*
Excellent	25	50	9	18
Good	12	24	17	34
Unsatisfactory	13	26	24	48
Satisfactory		74		52

Excellent = no back or sciatic symptoms and no restriction of activities since original operation.
Good = minor back or sciatic symptoms, slight restriction of activities.
Unsatisfactory = (a) moderate or severe back or sciatic symptoms, marked restriction of activities.
(b) re-operation for any reason.

syndrome nineteen years ago. About 30 to 40 per cent. of our disc cases have had the combined operation. Our Staff has been aware of the potential benefits to be derived from this operation, but we have also recognized its technical difficulties.

Two previous statistical studies (1941, 1947)[2,3] of the comparative results of disc excision and excision-fusion have been reported from our Hospital. In both of them the combined operation appeared to be somewhat superior.

Recently, a third series of our cases has been studied and is reported herewith (Tables V, VI, VII, VIII, IX, X).

CASE MATERIAL AND COLLECTION OF DATA

All records from the public and private wards of the Massachusetts General Hospital of patients operated upon for an intervertebral-disc lesion of the lumbar spine between January 1941 and January 1946 were reviewed. This group included 495 cases, of which 166 (33 per cent.) had the combined excision-fusion operation and 329 (67 per cent.) had excision only.

Mortality

There were three deaths, all in the excision-fusion group, attributed to the operative procedure. This is an operative mortality rate of 0.6 per cent.

End-Result Study

The end-result study was limited to cases in which:

a. The original operation was performed between January 1, 1941, and January 1, 1946.

b. The operative note described an unequivocal protruded lumbar-disc lesion with evidence of pressure on one or more nerve roots.

c. At the time of operation the patient's age was between sixteen and forty-five inclusive.

Excluding those known to have died since operation, there were 346 patients to whom letters were sent, asking them to report for interview and examination to determine the result of treatment. Approximately 40 per cent. of the patients have reported and have been examined by a physician who is not a member of the Hospital Staff. Fifty consecutive records of patients who had simple disc excision were compared with a similar number having the combined operation of excision-fusion. It will be noted (Table V) that there were more males in the group who had the fusion operation than in the group who had only excision, but that otherwise the two series were very similar. As the average time

since operation was over eight years and the minimum time was five years, this may be considered a long-term follow-up report.

Selection of Cases

Many surgeons, all members of the House and Visiting Staffs of the Neurosurgical and Orthopaedic Services, participated in the management of these cases. A few of those who had the excision-fusion were operated upon by a member of the Orthopaedic Service alone, but most of these patients had a "two-team operation", the disc excision being done by the neurosurgeon and the fusion by the orthopaedic surgeon. With an occasional exception, the patients who had excision only were operated upon by one of the neurosurgeons.

In general, our Staff maintains a conservative attitude toward disc surgery, reserving it for those patients whose symptoms have failed to subside under conservative treatment or who have evidence of severe root pressure, or who have had several recurrences. We prefer to operate during an acute attack.

The operative technique of the exposure of the lesion and its removal has changed little in the past ten years, and it is safe to assume that the results in the excision group are not influenced by variations in operative technique. A variety of techniques has been used for fusion. In general, an osseous bed was prepared by some modification of the Hibbs technique and supplementary bone was used in the form of iliac or tibial grafts. The H or clothespin graft (described by Bosworth) was not used in this series. The patients with excision-fusion averaged forty days' hospital stay following operation; the patients with excision only averaged eighteen days in the hospital after operation.

Complications

There was little difference in the two series of cases in this regard. Wound infection or phlebothrombosis occurred in five patients in each series.

Return to Work

In general, the patients who had had fusion were permitted to do heavy work six months after operation, while in the non-fusion cases full activity was resumed somewhat earlier, either on medical advice or of their own volition.

Relief of Sciatic Pain

This study confirms numerous previously reported observations on the efficacy of disc excision for the relief of severe intractable sciatic pain. End results showed that 97 per cent. of the patients were satisfactorily relieved of their sciatic pain. Paraesthesias (numbness or tingling) and muscle cramps were noted by some of the patients, but only 3 per cent. had symptoms of any severity referable to the lower extremity. There was no significant difference between the fused and unfused cases (Table VII).

Relief of Back Pain

At end-result examination, 58 per cent. of the patients with fusion and 22 per cent. of the patients without fusion denied having any back symptoms. Adding the patients with minor complaints to those with no symptoms, we find that 80 per cent. of the patients with fusion and 64 per cent. of the patients without fusion were essentially free of back symptoms (Table VIII).

Additional Operations (Table IX)

Two patients in the fusion group had been re-explored for a recurrent disc lesion. There were four re-explorations in the excision group.

Five patients who had had excision only, with disabling back symptoms, had undergone re-operation (fusion) for the relief of their symptoms; the operation successfully

relieved their disability in four of the five cases. Several additional patients in the excision series were considering having a fusion operation; others, although partially disabled, were unwilling to undergo further surgical measures.

Five of the patients who had had excision-fusion had undergone operations for repair of pseudarthrosis, with an excellent result in one, a good result in two, and a poor result in two. The incidence of pseudarthrosis was not accurately determined, as all patients were not subjected to roentgenographic examination with bending films; but we know that it was present in over 20 per cent. of the cases in which fusion was attempted. There were instances of completely satisfactory clinical results in the presence of a known pseudarthrosis, and, conversely, there were clinical failures when the fusion area was demonstrably solid.

The aim of operative treatment is to restore as many patients as possible to normal life. In Table X, an attempt is made to evaluate the result of the original operation in terms of success or failure in relieving sciatic symptoms and restoring normal back function. All cases requiring additional surgery (exploration, fusion, *et cetera*) after the original operation were classified as failures. Using these criteria, it was found that 74 per cent. of the combined operation cases were successful as compared with 52 per cent. of the excision cases.

DISCUSSION

The question of whether or not disc excision should be accompanied by fusion cannot be answered by an unequivocal "yes" or "no". The more cogent arguments pro and con may be summarized as follows.

Those who favor simple disc excision argue that the patients are usually operated upon for severe sciatic pain. The relatively simple excision operation relieves this symptom in 90 per cent. or more of the cases, and the few patients requiring re-exploration often have a second disc lesion. They note that most of the patients have been returned to their original occupation and that the result may be classified as good or excellent in 60 per cent. or more of properly performed disc excisions. An occasional poor result may be due to mechanical instability of the spine, but it is impossible to recognize preoperatively or at the operating table the indications for fusion. It is, therefore, wiser to subject a few patients to a fusion operation at a later date than to subject many patients to a needlessly complicated original operation, with its attendant risks and prolonged after-care.

Those who favor the combined excision-fusion operation argue that a protruded disc, traumatic or degenerative, means loss of its normal elasticity, narrowing of the disc space, and articular facet changes, and that the involved segment can never be restored to anatomical or functional integrity. It is, therefore, better to stabilize it by fusion than to take the risk of an unsatisfactory result due to pain and limitation of physical activity. They point out that the *additional* operating time required to do the fusion is ordinarily less than forty-five minutes. The additional period of recumbency required of patients with the combined operation has been reduced to about ten days. Forty-five minutes of the surgeon's time and two weeks of the patient's time are a modest investment from which the patient may derive life-long benefit.

Although indubitable statistical proof of the superiority of the combined fusion-excision operation is not yet available, there is strong evidence to support this view. Having made that statement, let us qualify it as follows. There is some additional operative risk in adding fusion to disc excision, and it should be omitted in cases with cardiac or other complications. A patient about to undergo disc excision should be told that his sciatic pain will almost certainly be relieved, but that he may suffer from chronic or recurrent back symptoms. He and the surgeon may then choose the relatively simple operation of excision, knowing that a later fusion may be necessary, or they may elect to undertake the combined operation of excision-fusion.

There is an obvious need for better techniques of fusion; the incidence of pseudarthrosis is much too high. However, although the difficulties and problems of the combined operation are fully recognized, it seems to give final results superior to simple excision.

In conclusion, let me again stress the fact that the low back is an extraordinarily complicated mechanism and that its anatomy, physiology, and pathology are still imperfectly understood. There is a great variety of etiological possibilities to consider when a patient presents himself with the complaint of low-back and sciatic pain. There is no substitute for painstaking evaluation of the individual problem. The surgical procedures of exploration and disc excision will relieve intractable sciatic pain due to disc protrusion in dramatic fashion. Low-back pain, however, is rarely relieved by disc surgery, and there is evidence that the operative trauma of exploration may occasionally damage spine function. Arthrodesis of weak or painful articulations is a well-tried and proved method of relief. It has a useful field in spine surgery, both as an adjunct to disc excision and as an independent procedure.

There is a world-wide interest in the problems of low-back disability, and we may confidently expect that better surgical techniques and, most important of all, broader, sounder concepts of the normal and abnormal physiology of the lumbosacral spine will reward the efforts of the adequately trained, intellectually curious physician.

NOTE: Dr. James Simpson, working under the direction of the Research Committee of The American Orthopaedic Association on a comprehensive study of the operative treatment of lumbar-disc lesions, collected the end-result data herein reported. His assistance is gratefully acknowledged.

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DISCUSSION

Analysis of Suction-Socket Wearers

(*Continued from page 627*)

faintly perceptible ischial weight-bearing shelf. I believe that, considering the individual variations of the anatomy of the ischial tuberosity, no standardization should be attempted and that greater attention must be paid to the situation of the muscles, especially of the glutaeus maximus, the hamstrings, and the posterior portion of the adductor magnus. It would be better to adopt the term "ischial support" in place of the misleading term "seat", for there is continually moving action during gait, and at no phase of the cycle is there a stationary moment of "sitting".

As regards the accessory belt, which is widely used in Germany under the name of Silesian bandage, I believe as do members of my staff, that in difficult cases, such as patients with short stumps or poor muscle strength, this type of soft belt helps to make for the successful use of the suction socket. The more expressive term "trochanter belt" should be applied, as it does not completely encircle the pelvis, but passes from the region of the greater trochanter across the posterior pelvis in a spiral descent to the anterior projection of the lesser trochanter.

At the New York Regional Office of the Veterans Administration we have combined the suction-socket seal with the conventional trochanter, joint, and pelvic belt for three patients with less than four inches of femur, who had had poor success with the conventional prosthesis. The seal eliminated the piston action and the pressure of one and one-half pounds added to the harnessing of the prosthesis.

At the New York Regional Office of the Veterans Administration, we have adopted the suction-socket type without seal for the conventional prosthesis which has helped to prevent the adductor roll so common in the ordinary conventional prosthesis.

I enjoyed Dr. Mazet's presentation and hope that, with increasing experience and research, every following report will show steadily improving results.

Dr. Charles O. Bechtol, Oakland, California: The authors are to be congratulated upon their well organized presentation.

There are several points which might well be re-emphasized: (1) No one socket shape or type of valve will be suitable for all amputees. (2) The commonest causes of failure are difficulty in fitting and inability of the patient to return frequently to the limb shop for fitting. (3) The commonest cause for fitting difficulty is flabby stump muscles. To test the state of the stump muscles, the amputee is asked to tense the muscles while the examiner grasps the stump with both hands and rotates the stump to each side. More than 20 to 30 per cent. of rotation will indicate that there will be difficulty in fitting. (4) Stumps in which the muscles are not adherent to the bone end are difficult to fit. Such stumps, when tensed, show a marked upward movement

(*Continued on page 782*)

OSTEOPERIOSTEAL RIBBON GRAFTS IN UNDISPLACED, UNUNITED FRACTURES OF THE TIBIA

BY IRVINE M. FLINN, JR., M.D., WILMINGTON, DELAWARE

In 1947, Phemister reported a series of cases of non-union in undisplaced fractures of the long bones which had been treated with osteoperiosteal grafts. These were essentially full-thickness solid bone grafts with periosteum attached. Bone repair was uniformly good.

Figures 1-A, 1-B, and 1-C show a case of an osteotomy of the tibia, performed for malunion and possibly incomplete union in which a ribbon graft was laid over the osteotomy site. This was done after the method of Moore and disclosed to the author's satisfaction that osteoperiosteal ribbon grafts could be trusted to unite and to form bone.

TECHNIQUE

In this paper, the use of osteoperiosteal ribbon grafts has been limited to cases of non-union of the tibia in relatively undisplaced fractures.

To obtain the ribbon graft, the periosteum is incised on both sides along the length of the graft to be taken. Small chips are raised by means of a chisel underneath the incised periosteum so that the graft itself is reasonably flexible, and the chips are attached individually to the strip of periosteum. In non-infected cases, the grafts may be obtained either from above or from below the fracture site; this avoids the necessity of an incision in the other leg.

The operative technique is quite simple: A semicircular incision is made to expose the crest of the tibia. When the crest has been exposed, care must be taken to leave the periosteum undisturbed. An incision is then made through the periosteum, preferably on the lateral aspect of the tibia. The periosteum, together with the muscles attached to it, is elevated from the lateral side of the tibia, above and below the fracture site. If a spur is present at the site of the non-union, it is removed, since its removal will allow the graft to be placed more closely against the fragments. Except for this, the fracture site is left entirely alone.

The graft is then cut, as previously described, and placed along the outer aspect of the tibia beneath the retracted periosteum. The bone side of the graft is placed against the fracture fragments; periosteum is placed against periosteum. The periosteum and the muscles attached to it, which had previously been elevated, are then sutured over the graft. Since no fixation of the graft is necessary, closure is completed at once. A cast is applied and allowed to remain in position for three months; however, if there is slight malposition, the cast may be wedged after two or three weeks to improve alignment. Three months after the procedure, the cast is removed, roentgenograms are made, and usually another cast is applied. Six months after the operation, the cast is again removed; at this time there should be clinical union and beginning definite union as shown by roentgenograms. Weight-bearing is begun.

CASE REPORTS

CASE 1. W. K., a white male, aged seventy-two years, was admitted to the hospital on November 8, 1946, with head injuries and a comminuted fracture at the junction of the upper and middle thirds of the right tibia and fibula. After the reduction of the fracture, the patient was discharged in a cast—only to be readmitted to the hospital on February 24, 1947, five months after the fracture, with non-union. At operation, an osteoperiosteal graft was taken from the lower part of the tibia and applied to the fracture site (Fig. 2-A). The cast was removed four months after the procedure, and the patient was allowed to walk with crutches. Nine months after the procedure, the patient was walking without support (Fig. 2-B); but, since he had had arthritis of the right knee, the actual time of weight-bearing was difficult to evaluate.

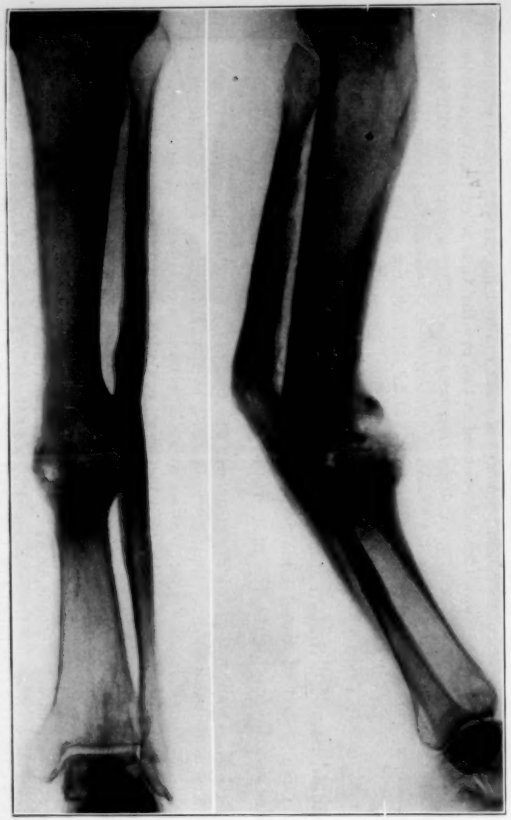

FIG. 1-A

M. H. July 9, 1947. Malunion with definite angulation is shown.

FIG. 1-B

November 20, 1947. Roentgenograms made two months after osteotomy and the placing of the ribbon graft. The ribbon graft is seen bridging the osteotomy site.

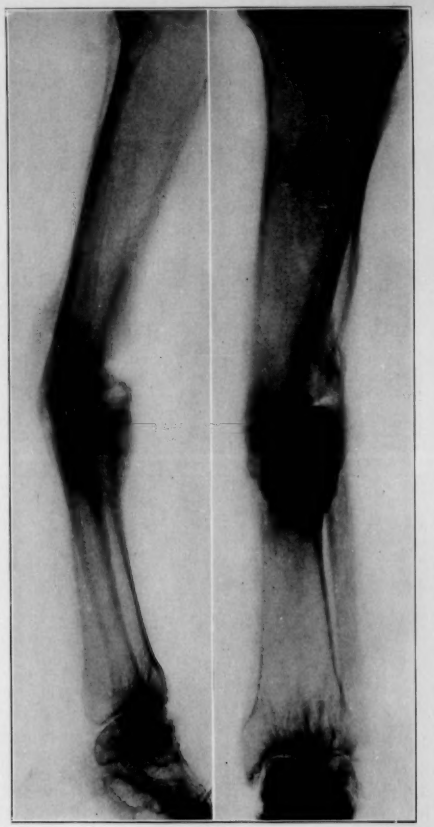

FIG. 1-C

September 1, 1948. One year after the operation, the union is shown to be complete. Note how the ribbon graft has been able to produce bone and to bridge the bony gap.

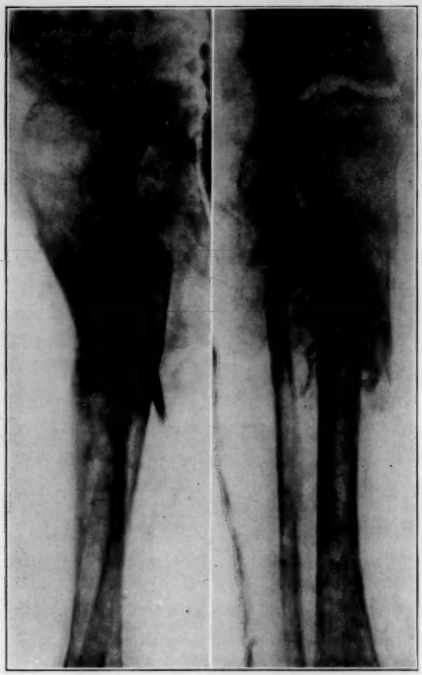

FIG. 2-A

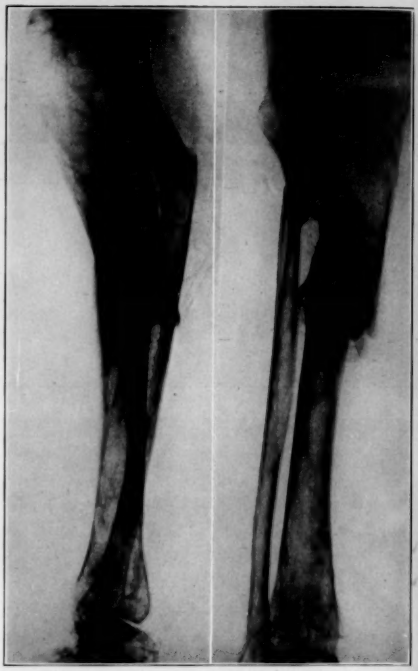

FIG. 2-B

Fig. 2-A: W. K. March 3, 1947. Roentgenograms made immediately after the operation, showing the graft in place.

Fig. 2-B: December 3, 1947. Complete union of the fracture is shown nine months after the operation. Note bar of bone in position of graft.

CASE 2. G. Y., a white male, aged seventy-seven years, was admitted to the hospital on December 1, 1946, with a comminuted fracture of the middle third of the right tibia and a simple fracture of the fibula at the same level. After failure of reduction by means of casts and wedging, he was treated with external skeletal fixation with a Stader splint. This was removed in two months' time when there was evidence of distraction; the fibula had united, holding the tibial fragments apart. After nine months with non-union the patient was readmitted on September 4, 1947. An osteoperiosteal graft was applied to the lateral surface of the tibia at operation on September 19, 1947 (Figs. 3-A and 3-B). Inasmuch as the fibula was felt to have held the fragments apart, it was osteotomized at the same time. There was some postoperative infection which was controlled by penicillin. In six months' time, the patient was walking without support.

It should be noted that in this case the fragments of the graft were very small and that the coalescence of these occurred quite rapidly. It would seem, from this, that the smaller are the fragments, the more rapid is bone production from the graft.

CASE 3. G. K., a white male, aged fifty years, was admitted to the hospital on December 17, 1947 with a compound comminuted fracture of the right tibia and a compound fracture of the right fibula. An inadequate plate was applied but was removed six weeks later because of infection about the screws. The patient was readmitted five months later with non-union of both fractures. Because of the infection in the right tibia, it was necessary, at operation, to take the osteoperiosteal graft from the left tibia. The roentgenograms and history of this case revealed more and quicker bone repair than occurred in previous cases.

The patient was walking in his cast long before it was removed six and one-half months after operation; but, because he was a chronic alcoholic, he was given a brace for added protection after the cast was removed.

In this case, the fragments of the graft were much larger than in the previous case.

FIG. 3-A

G. Y. June 25, 1947. Preoperative roentgenograms.

FIG. 3-B

September 22, 1947. Roentgenograms made immediately after the operation. The ribbon graft is visible lateral to the fracture site. Note the small size of the chips.

FIG. 3-C

May 5, 1948. Solid union of the graft and outer half of the tibia is shown. Union can also be seen progressing medially.

FIG. 4-A

FIG. 4-B

Fig. 4-A: J. A. May 17, 1948. Non-union present ten months after the injury.

Fig. 4-B: July 14, 1948. Roentgenograms taken immediately after the operation, showing the graft on the outer aspect of the tibia. The graft extends only a short distance below the fracture site. The cast was wedged to improve alignment.

At three months, however, the coalescence of this graft was almost as complete as the other had been, and union had been stimulated at the fracture site in the same way. Despite the fact that the upper portion of the graft had failed to unite to the shaft, the fracture united successfully.

CASE 4. J. A., a white male, aged sixty-one years, was admitted to the hospital on August 1, 1947, with a compound comminuted fracture of the middle third of the right tibia. The wound was closed and a cast applied. Later, a Stader splint was used. On August 21, 1947, a slight distraction was noted in the roentgenograms; however, he was discharged in a splint in six weeks' time. There was still non-union after ten months (Fig. 4-A). The patient was readmitted to the hospital on June 17, 1948. At operation, an osteoperiosteal graft was inserted (Fig. 4-B). Five months afterward the cast was removed and full weight-bearing was begun, even though he still had some pain in the region of the old pin wounds.

In this patient, the coalescence of the graft occurred throughout, except for one area just lateral to the fracture line (Fig. 4-C). This line can be seen in all roentgenograms made after the operation but the last (Fig. 4-D). The graft had been placed in such a way that only a small portion of it extended below the fracture level, and it appears that there may have been a non-union in the graft. The fracture itself united without difficulty.

CASE 5. L. MCN., a white male, aged twenty-four years, had been operated upon elsewhere previously for débridement of a compound fracture. He was admitted to the hospital with frank non-union of a fracture of the tibia and was operated upon October 7, 1947. Six weeks after the operation the cast was changed. Roentgenograms, made at that time, showed incomplete coalescence of the osteoperiosteal graft. Four months after the operation, roentgenograms pictured the graft still not united, clinically. When the cast

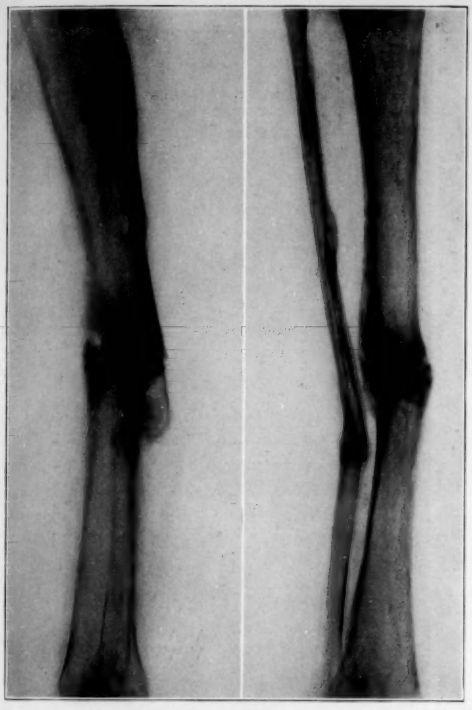

FIG. 4-C

FIG. 4-D

Fig. 4-C: October 27, 1948. Four months after the procedure, further coalescence of the graft is shown, with a definite interruption of continuity. The union of the fracture has become more firm.

Fig. 4-D: January 26, 1949. Seven months after the operation, there is solid union.

was changed again, two months later, roentgenograms showed union to be still incomplete. The patient was, however, walking at this time, apparently without pain or discomfort.

He had been lost sight of for six months when he returned with a definite failure of union (Fig. 5-A). The roentgenograms revealed the old non-union through the graft as well as through the tibial fragments. The graft itself extended only a little below the fracture site, and around it there was extensive callus formation. At operation, a new graft was applied, extending well below and well above the fracture site; the graft was sutured to the periosteum to prevent it from slipping (Fig. 5-B). Five months after this procedure, roentgenograms not only showed the union of the graft but also definite beginning union of the fragments (Fig. 5-C). Clinically, the fracture was solid, and the patient could walk without support.

In Case 4, there had been an apparent lack of union in the graft in line with the fracture, the graft barely covering the fracture site; union did, however, occur. The same thing happened in Case 5, but in this patient non-union resulted. The failure is due to two factors: First there was an error in technique in placing the graft too high on the fracture; second, the patient was not in our care for a period of time when he should have been under close observation. It might have been that bony union would have resulted if another cast or brace had been used to prevent strain.

CASE 6. N. T., a white diabetic female, aged forty-eight years, was admitted to the hospital with frank non-union of a fracture at the junction of the lower and middle thirds of the tibia. The injury had occurred six months previously. Roentgenograms showed the beginning of callus formation in a band laterally, but there was no sign of union medially. There was also motion at the fracture site. At operation, to stimulate union, an osteoperiosteal graft from the tibia above the fracture site was placed diagonally across the medial aspect of the fracture which was not otherwise disturbed. Following the operation, the skin sloughed medially and was very slow to heal, although the diabetes was kept under control. The patient was walking in three and one-half months without support. The roentgenograms show the coalescence of the graft and a filling in

FIG. 5-A

FIG. 5-B

FIG. 5-C

Fig. 5-A: L. McN. November 3, 1949. The failure of the first ribbon graft is shown. The graft extended only three-quarters of an inch below the fracture line. The extension of the fracture line through the graft should be noticed.
Fig. 5-B: November 26, 1949. After the operation. The ribbon graft is shown in position.
Fig. 5-C: September 13, 1950. Ten months after the operation. Further coalescence of the graft with increased union of the shaft is shown.

FIG. 6-A

FIG. 6-B

FIG. 6-C

Fig. 6-A: N. T. February 24, 1949. Roentgenograms taken immediately after the operation. The ribbon graft is shown medially.
Fig. 6-B: April 12, 1949. Two months after the operation. Roentgenograms show the beginning coalescence of the graft and suggest early union of the shaft.
Fig. 6-C: October 11, 1949. Eight months after the operation, there is solid union.

of the defect of the tibia at the site of the fracture (Figs. 6-B and 6-C). The ulcer, however, did not completely heal for seven months. Perhaps, as in Case 1, this was a case of delayed union rather than non-union, and as in Case 1, union occurred early after insertion of the graft.

CASE 7. E. H., aged forty-four years, was admitted to the hospital with a high fracture of the tibia which, because of repeated manipulation, had not united. After three and one-half months there was no evidence of union. At operation, osteoperiosteal grafts were placed medially and laterally at the site of the fracture. It took a surprisingly long time for this fracture to unite following the operation,—seven and one-half months.

CASE 8. J. F., a colored male with syphilis, aged seventy, had sustained a compound comminuted fracture of the tibia at the junction of the lower and middle thirds. A frank non-union resulted, with purulent drainage. The penicillin given for his syphilis did not clear up the infection. At operation, an osteoperiosteal graft was applied to the fracture away from the drainage tract. Penicillin was again given, and, this time, all wounds healed in two months. At the fracture site, there was only springy motion. He was walking in six months without support.

CONCLUSIONS

The exact mechanism by which the ribbon graft stimulates union is not known. In all cases, the fragments of the graft began to show coalescence before there was a real attachment of the graft to the tibia itself. During the preliminary stages, union began to appear between the fragments of the tibia; at three months the graft had coalesced and had begun to unite with the tibia. In Case 4 and Case 6, union had been sufficiently stimulated by this time, so that clinically there was no motion and the patient could walk without support. It would seem, therefore, that the graft initially stimulates callus formation in the fracture region locally and that the bone-forming elements there begin to assume their proper functions. After three months, coalescence of the graft occurs, at which time it may serve as a strut, allowing the rest of the fracture to unite.

Regardless of the mechanism, there are several highly desirable features of this type of graft. Avoidance of the fracture site, except for creating a suitable bed in which to place the graft, means but a minimum of disturbance of the blood supply to that region. Minor operative trauma and early coalescence of the graft make this also a helpful adjunct in the treatment of delayed union. Because of the relatively short operative time and the simplicity of the procedure, it can be used in patients of all age groups.

Union occurred in all of these cases except Case 5. It was necessary to repeat the procedure in this single failure, and successful union resulted. An analysis of this failure revealed that the graft did not span the fracture line sufficiently. This error in technique also occurred in Case 4, but union occurred in that patient despite the error.

From a consideration of the cases reported, the following observations seem true:

1. Osteoperiosteal grafts of the ribbon type coalesce and unite to the shaft in approximately three months' time.

2. By their presence, union is stimulated within the fracture. In six months' time, there is a solid bar of bone across the fracture and union of the fracture has progressed sufficiently far so that weight-bearing without support is begun.

3. Infection is no contra-indication, when the graft is placed in a non-involved area. Union will occur in the same manner as in non-infected cases.

4. The smaller the chips in the ribbon graft, the quicker the graft itself unites solidly into a bar of bone.

5. Non-fixation of the graft is important, but proper placing of the graft is essential. It must lie well above and below the fracture site. One graft placed so that it extended insufficiently below the fracture site resulted first in partial union, and later in non-union.

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ONE HUNDRED FRACTURES OF THE FEMUR TREATED BY MEANS OF THE DIAMOND-SHAPED MEDULLARY NAIL*†

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HISTORY

The principle of medullary fixation in fractures of the long bones was evolved during the present century. Its earliest use appears to have been in 1907 by Lambotte, who employed screws in fractures of the clavicle and in subtrochanteric fractures of the femur. Intramedullary ivory or bone pegs were employed following the work of König in 1913.

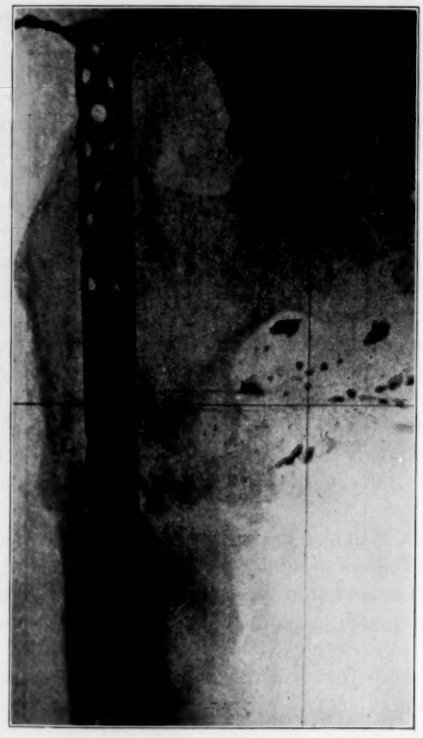

FIG. 1-A

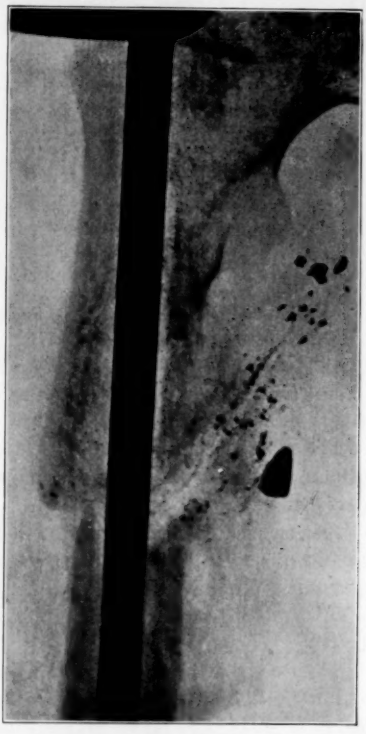

FIG. 1-B

Roentgenograms from two cases of Hey Groves, showing tubular and solid nail. (Reproduced from *The British Journal of Surgery* 6: 203–247, 1918, by permission of John Wright & Sons.)

In 1918, Hey Groves reported three cases of fracture in the proximal third of the femur, in which he used medullary nails of three different patterns. The first, a perforated steel

* Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the author are a result of his own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

† Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 13, 1950. Revised manuscript received for publication February 2, 1951. Illustrations received April 16, 1951.

tube, and the second, a steel rod of cross-shaped section, are shown in Figures 1-A and 1-B. The third was a solid rod, presumably round. Since his cases were of gunshot fractures, his problem was chiefly one of infection, and he thought the solid rod best because of "an avoidance of hollows or crevices which form dead spaces". Although the nails spanned the medullary canal, they were somewhat short, extending only several inches into the distal fragment. He inserted them retrograde, by a method essentially the same as that used today.

According to Soeur, medullary Kirschner wires were used by Danis in 1935 and also by Joly in Belgium for fractures of the forearm and for the metatarsals and other small bones. Lambrinudi, in 1940, reported on using wires in the forearm and multiple wires in the femur. In the same year Murray reported on using wires in the clavicle, and in 1944 Dickson reported the use of wires in the forearm. Multiple wires were also used in the femur by Wheeler in 1947.

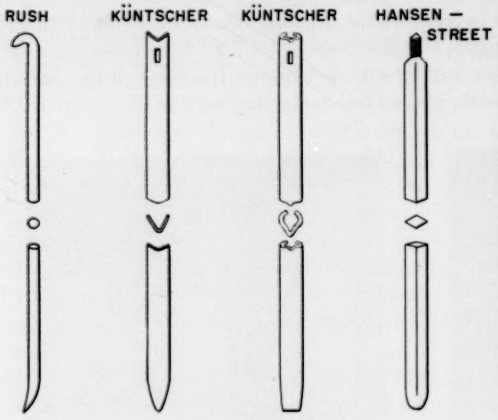

FIG. 2
Types of nail in common use at the present time.

Steinmann pins inserted in the axis of the ulna and of the femur were reported by L. V. Rush in 1937 and 1939. He has since modified the ends of the pin to a hook and sled-runner point and has designed nails of different sizes for use in other bones. (Fig. 2).

Until the publication of Küntscher's work in 1940, these remained isolated instances of medullary nailing. Following Küntscher's report the technique began to be widely used and was adopted throughout Europe under the impetus of war surgery. In Küntscher's method, the nail not only spans the canal but extends through a major portion of its length. The fixation thus obtained is so solid that a cast or other external fixation is not necessary and early ambulation is possible, so that joint motion and muscle power can be maintained. Bone contact is also assured since the fragments can slide on the nail.

Küntscher's nail has been modified from a V-shaped design to one with a clover-leaf shape in cross-section which is stronger and follows a guide pin better. The V-shape is preferred by Romney in Cuba, Brüner in Switzerland, and Westerborn in Sweden. It has the advantage that if one nail is not strong enough, a second one can be driven down, following the groove of the first.

Due to the fact that European periodicals did not reach us during the War years, it was not until 1945 that surgeons in this country began to make use of this method. In the fall of 1945, Dr. H. C. Hansen designed the diamond-shaped nail, and together we inserted the first four nails of this type.

The series of cases here presented includes only those in which the diamond-shaped nail was used. Forty-two of the cases are the author's, the remaining fifty-eight having been contributed by eight other surgeons. All cases, good or bad, have been included to provide an unbiased impression of the indications, complications, and results which may be expected with this method. The follow-up period ranges from six months to four years, with an average of 15.7 months. The total number of fractures nailed by these surgeons up to six months before the original report in 1950 was 100. Ten cases were eliminated from the analysis of results because the last visit had been less than six months following nailing.

Technique of nailing:

FIG. 3-A

Fig. 3-A: The nail is inserted retrograde into the proximal fragment and follows the axis of the canal.

FIG. 3-B

Fig. 3-B: The nail is driven up through the trochanter without comminution, and drilling the trochanter is unnecessary.

FIG. 3-C

Fig. 3-C: The skin is incised when the point of the nail is felt subcutaneously, and the nail is driven up until its distal end is at the fracture site.

FIG. 3-D

Fig. 3-D: The fracture is reduced and held with a clamp while the nail is driven into the distal fragment.

TECHNIQUE

There are two fundamentally different techniques for inserting the nail. In the closed method the fracture is reduced by closed manipulation under fluoroscopic or roentgenographic control and the nail is inserted from above through the trochanter. This method can be used only in fresh fractures and in ununited fractures in which the fragments have not been displaced, since accurate reduction by manipulation must be obtained.

In the open method the fracture is exposed and reduced under direct vision, and the nail can be inserted either from above or retrograde through the proximal fragment. Open reduction is necessary in cases requiring revision of callus; removal of plates or screws after unsuccessful fixation; insertion of supplementary wire sutures or screws; reduction of a segmental fracture; or osteotomy for malunion, femur shortening, or femur lengthening. Furthermore, the open method is preferable as it is more precise and requires less experience in manipulation, and the operative time is more predictable.

Küntscher advocated the closed method, where applicable, to avoid infection which may result from exposing the fracture site. In the present series, eleven cases were treated by closed and eighty-nine by open reduction. The closed method is not without danger, to the patient as well as to the surgeon, because of injuries resulting from exposure to x-ray; in this series a burn was incurred on the inner aspect of one patient's thigh. The risk of infection in open reduction does not appear to be great, as only two cases out of eighty-nine showed evidence of infection.

Both the length and the diameter of the nail to be used should be determined prior to operation. The length of the sound femur may be determined exactly by roentgenogram; however, we have found measurements taken from the tip of the trochanter to the knee joint, with the hip and knee flexed, sufficiently accurate. From this measurement we subtract one inch in most cases. Two noteworthy exceptions are the unusually low fractures and those in the very obese patient. In the former a full-length nail is used and checked fluoroscopically or by roentgenogram as it approaches the knee joint, while in the latter an additional amount must be subtracted to allow for the thickness of soft tissue overlying the trochanter.

The diameter of the canal can be measured on the roentgenogram and, according to Fischer and Maatz, is actually about one millimeter less. Böhler allows two millimeters for the femoral cavity, and about one millimeter for the cavity in other bones. Studies of the medullary canal by Böhler, as well as our own studies, show the canal to be oval in cross section in most cases, the sagittal diameter being greater on the average by two to three millimeters. Since the diamond-shaped nail has two diameters, we then have the interesting effect of two sizes in one nail. If the size of the canal permits, the nail is inserted with its greater diameter transverse in order to forestall lateral bowing. If, on the other hand, the canal is too narrow to take the nail in this plane, it can often be easily inserted in the sagittal plane. We have had no difficulty in using a nail of 11 millimeters when the narrowest portion of the canal measured ten millimeters or greater in the anteroposterior roentgenogram. Obviously the 11-millimeter nail is stronger than the 9-millimeter nail and is therefore preferable. Only two 9-millimeter nails were used in this series.

The technique which we believe to be the simplest, most reliable, and safest consists in open reduction with retrograde insertion of the nail (Figs. 3-A, 3-B, 3-C, and 3-D). The patient is placed on his uninvolved side with the hip and knee flexed. The fracture is exposed through a posterolateral approach, since there seems to be less interference with quadriceps function. The nail is inserted into the proximal fragment and driven retrograde out through the trochanter, with little or no comminution of the thin cortex in this region. The skin is incised when the point of the nail can be palpated subcutaneously. The driver is next screwed into place and the nail is driven further upward until the distal end is at the fracture site. The facture is then reduced and held with a clamp while the nail is

FIG. 4-A FIG. 4-B

The most proximal fracture in the series, 10 centimeters below the tip of the greater trochanter. Butterfly fragment screwed to proximal fragment increases effective length.

FIG. 5-A FIG. 5-B

The most distal fracture in the series; the osteotomy was made 10 centimeters above the knee-joint line.

FIG. 6-A FIG. 6-B

Fractured femur with a split segment, requiring nailing and supplementary screw fixation.

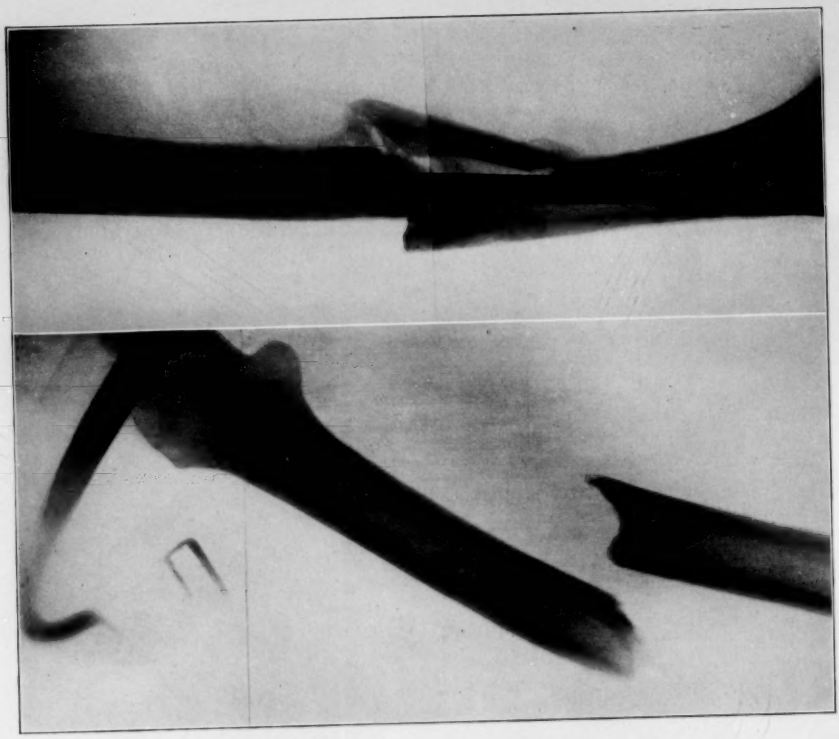

FIG. 9-B

FIG. 9-A

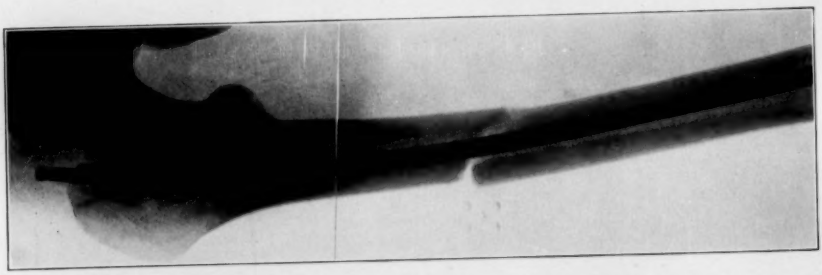

FIG. 8

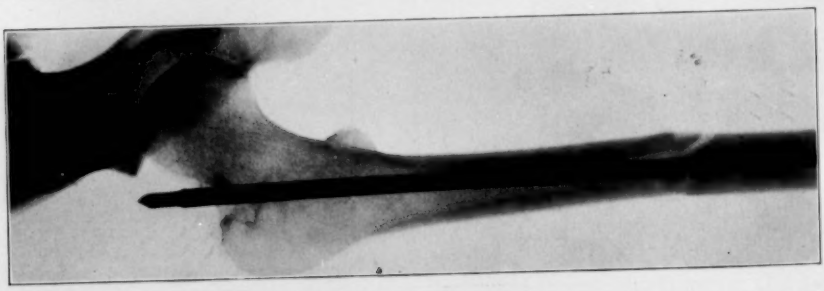

FIG. 7

Fig. 7: The nail, introduced from above, was started at a point too far medially and hugged the medial cortex, causing a slight angulation at the fracture site.

Fig. 8: In this patient the nail, also introduced from above, struck the lateral cortex and was bent during insertion; this resulted in lateral bowing.

Figs. 9-A and 9-B: A longitudinal fissure is visible in the distal fragment, illustrating undisplaced comminution. Failure to stabilize this with screws resulted in displacement after nailing.

driven into the distal fragment. Postoperatively the limb is suspended in a Thomas splint, with Pearson attachment, for three weeks, while the patient is encouraged to exercise the entire extremity. Partial weight-bearing on crutches is then begun and the amount of weight is gradually increased until the crutches are discarded, usually at six weeks.

INDICATIONS

As outlined by Küntscher, this method is most effective in fractures of the femur located at the isthmus or narrowest portion of the canal, which is usually just below the junction of the upper and middle thirds. However, Küntscher felt that medullary nails could be used to advantage in other fractures of the shaft. Böhler placed the upper limit at seven centimeters from the tip of the greater trochanter, and the lower limit at seven centimeters from the knee joint, while Romney advocates upper and lower limits of eight and ten centimeters respectively. These are not absolute limits but should serve to indicate that the closer the fracture line approaches either extremity of the bone, the less secure is the fixation and the more care is necessary in postoperative management. In our series the fractures ranged from ten centimeters below the tip of the greater trochanter to ten centimeters above the knee joint, with the greatest number in the middle third. In the case where the fracture was closest to the greater trochanter (Figs. 4-A and 4-B) two supplementary screws were used because of a butterfly fragment; in this patient the limb was supported in a balanced suspension until partial weight-bearing on crutches was begun at three weeks. In the case in which the fracture came closest to the lower limit a supracondylar osteotomy was performed in which a small supplementary wire suture was used to control rotation. Here, too, the limb was supported in a balanced suspension, but partial weight-bearing was postponed until six weeks (Figs. 5-A and 5-B). Full weight-bearing was begun at six and eight weeks respectively in these cases. Note that a maximum of nail length was employed in the latter case.

Extensively comminuted fractures were originally thought to be unsuitable for this method (Figs. 6-A and 6-B). Böhler has advocated supplementary fixation by means of wire sutures. We have found screws to be more secure and used these in eleven cases. Supplementary screws may be advantageously employed in fractures with butterfly fragments, split tubular segments, and undisplaced comminuted fragments, as well as in oblique fractures when the canal is wide and in any fractures near the lesser trochanter or in the supracondylar region.

Segmental fractures are particularly amenable to this form of treatment, since it is easy to fix the fragments securely by threading them on the nail. A medullary nail can also be used effectively for immobilization in a cuneiform osteotomy for correction of angulation deformity; this was done in two cases in this series. Shortening of the femur by removing a segment of bone in the region of the isthmus can be easily accomplished with medullary-nail fixation. Böhler describes transverse and oblique osteotomies. We prefer a serpentine osteotomy made by multiple drill holes, and the use of a jig to ensure congruity of the apposing surfaces. There were three cases of shortening of the femur in this series.

Neither Küntscher nor Soeur advocate the use of medullary nails in compound fractures. Böhler believed that it was indicated in fresh compound fractures; but, in such cases, he did not close the muscle or fascial layers. In this series there were three cases of compound fractures. In each the operation was delayed two to three weeks while antibiotics were given. No evidence of infection appeared in any of these cases and union was prompt.

COMPLICATIONS AND RESULTS

Certain complications may occur during the operation. Of these fat embolism has been feared most. While mild fat embolism in a subclinical form appears to be common, as evidenced by fat in the sputum and urine, the clinical form is rarely seen. This condition developed in only one patient in this series; it appeared before nailing. Subsequent nailing of both femora brought no recurrence.

There were no cases in this series of splitting of the femur from too large a nail, or jamming of the nail so that it had to be sawed off. Since no guide pin is used with the diamond-shaped nail, there were no complications incident to using a guide pin, such as the pin jamming in the nail, slipping out of the groove, or not following the axis of the canal.

FIG. 10-A FIG. 10-B

A segmental fracture, one of the two cases in which infection developed. Several sequestra were removed and the lesion ultimately healed without shortening.

In two cases in which the nail was inserted directly from above it was introduced too far medially. In the first case this caused a mild medial bowing (Fig. 7). In the other, the nail struck the lateral cortex of the proximal fragment and bent while being inserted, causing lateral bowing (Fig. 8). Neither of these mechanisms was seen when the nail was inserted retrograde, since it then followed the axis of the canal. In one case of a fracture in the upper third, the nail after being properly inserted cut laterally through the trochanter until it impinged upon the lateral cortex of the proximal fragment, resulting in a mild coxa vara deformity.

Difficulties may also arise from the failure to detect an incomplete or undisplaced comminution; this occurred in two of our patients. The fragment may later become displaced, with overriding and angulation, particularly if the nail is somewhat short (Figs. 9-A and 9-B). It is safer to use a nail of adequate length in all cases and to reinforce all incomplete fracture lines with screws.

The remaining complications to be discussed occur during convalescence. The purpose of any method of fracture treatment is to secure union with the least amount of deformity and minimum loss of function in the shortest possible time. As infection can defeat this purpose in all four respects, the possibility of infection extending along the nail and thus involving the entire bone has been greatly feared. However, reports from the German literature indicate that even though the infection extends the full length of the nail, the cortex of the bone is seldom involved as it is in hematogenous osteomyelitis, and the course is usually mild. In this series two patients showed evidence of infection. The first, a case of segmental fracture, had two intermediate fragments, one of which was split longitudinally (Fig. 10-A). Several small fragments sequestrated and were removed over a two-year period. In this case, union was finally obtained and the patient retained the full

FIG. 11-A

FIG. 11-B

FIG. 11-C

In a comminuted fracture treated by a long slotted plate, non-union resulted and the plate broke after six months. There was prompt union after nailing.

length of the extremity (Fig. 10-B). The second case showed no evidence of infection after the nailing, but pain developed at the fracture site one year later when the nail was withdrawn. There was drainage from the proximal wound for two months; after that the wound healed, and the patient has had no trouble over a two-year period.

At first Küntscher was of the opinion that nailing stimulated callus formation. Böhler believed that it sometimes delayed formation of callus. In this series the presence of callus was revealed by roentgenogram at from sixteen to seventy-eight days, with an average of twenty-nine days. Consolidation was well marked at from sixty to 191 days, with an average of 113 days. This bears out a previous study [17] which indicated that nailing does not appreciably stimulate or delay callus formation.

The fact that seventy-three fresh fractures promptly united, while encouraging, is not so surprising as the union of seventeen fractures upon which other methods had been tried without success. The unsuccessful types of fixation included skeletal traction, slotted plate, dual plating, onlay bone graft, plate with a bone graft, medullary bone peg and multiple transfixion screws. Of the ninety cases followed for six months or longer, union resulted in eighty-eight. The remaining two patients had no pain and their fractures remained stable, but roentgenograms taken at forty-six and fifty-four weeks showed a persisting fracture line, and callus was not sufficient for complete union. Even if these two

fractures fail to unite, the total of cases with non-union in this series will be only 2.3 per cent.

Shortening and resulting deformity is seldom a problem in medullary nailing, as shortening can result only from overriding of an oblique fracture, displacement of comminutions, loss of bone substance, or angulation. Displacement can usually be controlled by supplementary fixation. Loss of bone substance from infection and sequestration is rare. Angulation generally can be corrected by straightening the nail.

In eight patients the nail was bent at the fracture site as a result of sudden trauma during the first few months of their convalescence. The amount of bend ranged from 4 to 30 degrees. One nail was removed and not replaced, two were replaced by straight nails, two were straightened under anaesthesia, and three were not straightened. One of the latter was removed without difficulty after the fracture had solidly united in spite of a 20-degree bend.

When a nail breaks this usually occurs late, as a fatigue fracture of the nail in patients whose fractures have not united. There were no broken nails in this series.

Joint stiffness, which so frequently results from prolonged immobilization by other methods of treatment, has been absent or of minor degree in these cases. Knee motion was recorded at three months in thirty-six patients and at six months in thirty-three; it averaged 79 per cent. and 94 per cent. of normal respectively.

A glutaeus medius type of limp was observed in many patients when they resumed full weight-bearing. This varied considerably in degree and usually disappeared after about two months. A few acquired a habit of limping which was difficult to overcome. Two patients in whom the nail projected an excessive distance above the trochanter (one and one-half to two inches) continued to limp and a bursa, filled with a brownish fluid and rice bodies, developed around the end of the nail. In some cases a bony cap formed over the end of the nail or a bony collar around the nail close to the femur. This was found in twenty-five patients.

Although our usual postoperative regimen called for full weight-bearing at six weeks, the group of patients in this series became ambulatory on crutches at an average of forty-seven days and fully weight-bearing at seventy days. Earlier weight-bearing in many of these cases was delayed by associated fractures.

The complication of migrating of the nail has aroused considerable interest. Apparently the nails rarely migrate into the knee joint; if they move at all, they move in the proximal direction. Böhler believes that this occurs when the nail is too short and fixation is therefore insufficient. In this series only five nails migrated, the distance ranging from eight millimeters to fifteen centimeters. The migration usually occurred early, before consolidation of the callus. In two patients the nail backed out until the distal end nearly reached the fractured site. One of these was driven back down and anchored with a suture, while the other was extracted, since the fracture appeared solid. In all cases the nails were somewhat short, and none reached within 4.5 centimeters of the knee-joint line.

SUMMARY

The simplest and most generally applicable technique of medullary nailing is open reduction with retrograde insertion of the nail.

Callus formation was unimpaired and the fracture united in all but two of ninety cases; in seventeen of these previous attempts at fixation had been unsuccessful.

Disability is greatly reduced and the patients undergo less pain and fewer complications than when treated by other methods.

NOTE: Grateful appreciation and thanks are extended to the following doctors who assisted by contributing cases to this series: Dr. Charles T. Berry, Dr. Robert G. Brashear, Dr. Louis W. Breck, Dr. Ernst Dehne, Dr. Thomas S. Robertson, Dr. Ralph E. Rowen, Dr. Harold A. Sofield, and Dr. Fred L. Stuttle.

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DISCUSSION

Dr. F. H. vom Saal, New York, N. Y.: I want to congratulate Dr. Street for a very fine piece of work. When you take 100 fractures of the femur, some of them quite bad and come out with 97.7 per cent. of union, that is not only a good method; it is very good surgery. But union is not the only criterion of successful fracture treatment. These patients also have good function and had relatively short hospitalization, and that is what really sums up the argument for intramedullary pinning. Union can be obtained by many methods, but this is the only method which will produce union while at the same time preserving function and cutting hospital costs. With the present cost of hospitalization, this is no longer an unimportant item.

I have not used Dr. Street's nail, all of my cases having been done with a clover-leaf pin, but there are several things about this paper which interest me. While the recommended time before full weight-bearing at his hospital was six weeks, Dr. Street tells me that he now gets some of his patients up in five days. I would like to make a plea for early ambulation. Fixation of the fracture is most secure immediately after insertion of the pin if it is done properly. The man who keeps his patients with nailed fractures in bed is not a conservative; he is a radical, because he is asking for trouble. Eventual absorption tends to loosen the pin. If the patient is kept in bed, atrophy accompanies the absorption and makes the fracture still less secure. Early ambulation prevents atrophy and hastens union by jamming the bone ends together and eliminating the absorption zone. I think the fractures in my patients united much more rapidly than those in Dr. Street's patients, not because of anything in the nail itself, but because in walking the two ends of the fracture are jammed together. Once the bone is pinned, union is assured and the patient can be treated for a soft-part injury. I have the patient walk as soon as the condition of his soft parts will allow. Patients with femoral shortening get up in twenty-four hours. Patients with traumatic injuries walk in from two to five days. The average period of hospitalization in my first fifty cases of fractured femora was twelve days, and the patients walked out of the hospital. Just think of the difference in the course of recovery alone.

Dr. Street speaks of measuring the pins before operation. I congratulate him if he can do it; I can't. I do open operation in all my cases and I think it the method of choice. If an open operation is done, it

(*Continued on page 678*)

RESULTS IN MEDULLARY NAILING OF NINETY-FIVE FRESH FRACTURES OF THE FEMUR

BY DR. JÖRG BÖHLER, VIENNA, AUSTRIA

From the Unfallkrankenhaus, Wien *

One hundred and fifty-one operations with medullary nailings of the femur were performed in the Vienna Accident Hospital between 1941 and 1948. In addition to this, there were seventy cases of medullary nailing performed in an army hospital during the War, and thirty-two cases treated during 1949.

The present study deals only with fresh fractures of the femur, a total of ninety-five cases.† The total number of fractures of the femur treated between July 1, 1941 and December 30, 1948 at the *Unfallkrankenhaus* was 988. As only 151, or 15.3 per cent., of these were treated by medullary nailing, it is evident that medullary nailing is indicated in a comparatively small number of cases.

For an evaluation of the results we have divided our series into the following groups.

Group I	Closed Fractures		61
(A)	Treated by closed nailing	58	
(B)	Treated by open nailing	3	
Group II	Fresh compound fractures		26
(A)	Treated by closed nailing	3	
(B)	Treated by open nailing	23	
Group III	Fractures in pathological conditions		8
(A)	Treated by closed nailing	6	
(B)	Treated by open nailing	2	

Group I (A) comprises cases treated during two periods: those treated betwen 1941 and 1942, when the indications for the operation were not yet defined and the technique had not been sufficiently developed, and those treated between 1943 and 1948, when the technique had been perfected.

In 1943 the chief of the Hospital, Dr. Lorenz Böhler, analyzed the results in all our cases and in a large number of cases operated upon in other hospitals. Following this, he determined exact directions for medullary nailing, which he also published in his book.[3] These include indications for the operation, prevention of shock, and the technical details of the procedure. A reduction apparatus for closed medullary nailing was devised. Since then the thickness and length of the nail to be used have always been determined before the operation. Above all, the purpose of the procedure is to attain a stable fixation of the bone fragments. We feel this to be most important, because the purpose of medullary nailing is to allow full use of the extremity after the wound has healed without any external support. If this cannot be achieved by closed medullary nailing, the fracture site should be exposed and secured with additional wire sutures, otherwise the operation is not indicated at all. Since we have followed these specifications, the results have improved markedly.

An amazing improvement in results was seen in the patients treated between 1943 and 1948, when medullary nailing had passed the experimental stage and had developed into an operation with exactly defined indications and techniques.

Results in Group I (A) During the Period 1941–1942

Deaths: None of the patients died, since the operation was never performed while the patient was in shock. Several deaths in cases of closed medullary nailing have been reported in the literature.

*Director, Prof. Dr. Lorenz Böhler.

† A study of all our cases, with a detailed analysis of every case, is to be published elsewhere.

TABLE I

RESULTS IN GROUP I (A)

(Fifty-eight closed fractures of the femur treated by closed medullary nailing)

Period	Excellent		Good	Fair	Poor	Total
	Number	*Per cent.*				
Patients treated in 1941 and 1942	8	30	8	5	2	23
Patients treated between 1943 and 1948	29	83	4	2	0	35
Total	37	64	12	7	2	58

Amputations: There were no amputations in this series.

Infection: Infection occurred in one case. Medullary nailing was later found to be contra-indicated, because of infected burns at the site of insertion of the nail. There are still fistulae and osteomyelitic "flare-ups" eight years after the operation. Therefore, in case of infection, we now remove the medullary nail as soon as possible.

Shortening: Shortening of three and four centimeters occurred in two cases. In five cases there was shortening of from five-tenths to two centimeters.

Rotation: Two patients showed outward rotation.

Angulation: One patient had angulation of 15 degrees. In six other cases there were minor angulations of from 5 to 10 degrees.

Inadequate Fixation: In fifteen of the twenty-three cases of the first period, the fracture site was not quite stable after operation. In ten of these cases, additional external cast fixation was necessary. In the latter cases, closed medullary nailing should not have been attempted.

Mobility of Knee Joint: In four cases, flexion of the knee joint was less than 90 degrees; in two of these cases this was due to other injuries. In two other cases, flexion, although limited, was possible beyond 90 degrees. In the rest, there was complete free motion.

Results in Group I (A) During the Period 1943–1948

Deaths: None.

Amputations: None.

Infection: None.

Angulation: One patient had a heavy fall four months after the operation and angulation of 8 degrees resulted. This is the only case where angulation of the nail itself occurred.

TABLE II

COMPLICATIONS IN GROUP I (A)

Complications	Patients Treated Between 1941 and 1942	Patients Treated Between 1943 and 1948
Deaths	0	0
Amputations	0	0
Infection	1	0
Angulation of from 5 to 10 degrees	6	1
Angulation of from 10 to 20 degrees	1	0
Shortening of from 0.5 to 2 centimeters	5	1
Shortening of from 2 to 4 centimeters	2	0
Rotation	2	0
Fracture fixation not stable	15	0
Cast fixation	10	0
Minimum range of knee motion 180 to 90 degrees	4	2
Less than 90 degrees of knee motion	2	2

Shortening: In one case there was shortening of one centimeter.

Mobility of Knee Joint: In two cases, flexion of the knee joint was less than 90 degrees. Both patients were transients and follow-up was not possible. In two other cases, the knee could be flexed over 90 degrees but some limitation was present. In the other thirty-one cases, range of motion in the knee joint was normal.

No patient was dismissed from the hospital until he was able to walk with the aid of only a cane. The time of treatment was relatively long, because patients were not dismissed from treatment until they could resume heavy labor.

Results in Group I (B) (Three closed fractures of the femur treated with open medullary nailing)

We were always reluctant to recommend open reduction with medullary nailing. By means of our reduction apparatus, specially devised for medullary nailing, we were almost always able to perform closed reduction and nailing. However, the results in all three cases of open nailing were excellent. Since 1948, with the advent of modern antibiotics, we have done more open medullary nailings. These cases are treated by means of additional bone sutures with one-millimeter stainless-steel wire. With this procedure, a firmer fixation of the fragments can be achieved in a greater number of cases than with closed medullary nailing.

TABLE III

AVERAGE DURATION OF TREATMENT IN GROUP I (A)

Period		No. of Days Hospitalized	No. of Days of After-Care	Total No. of Days of Treatment
1941 to 1942	Patients with other injuries	76.8	128.2	205
	Patients without other injuries	60.8	118.2	179
1943 to 1948	Patients with other injuries	45.8	145.2	191
	Patients without other injuries	30	137	167

Results in Group II (Twenty-six fresh open fractures)

Medullary nailing proved to be of special value in fresh open fractures of the femur. Many authors disapprove of the use of the medullary nail for this injury and report unfavorable results[5,8]. We treated almost all of our open fractures of the shaft of the femur with medullary nailing and additional wire sutures. Two contra-indications were recognized; the first was a poor general condition of the patient, and the second was a fracture in which the fracture line involved the joint. An example of the wide latitude of indications is a case of severely comminuted fracture discussed in a previous article.* In spite of this wide latitude and in spite of the fact that the first seventeen cases in this group were treated without penicillin, only one minor infection, with no permanent disability, occurred. With the exception of two cases, medullary nailing was done within the first twelve hours after the accident, after thorough débridement and primary closure of the wound. In one case, closed medullary nailing was performed eleven days after the accident because of severe shock, and, in another case, open medullary nailing was performed seven weeks after the accident. In two other cases, closed medullary nailing was performed immediately after wound closure.

In Group II the cases are divided into those treated before penicillin became available and those treated since the advent of penicillin.

* Küntscher's Medullary Nailing. J. Bone and Joint Surg., 31-A, p. 299, Figs. 4-A to 4-D, April 1949.

TABLE IV

RESULTS IN GROUP II
(Twenty-six fresh open fractures)

Period	Excellent	Good	Fair	Poor	Death	Total
Patients treated between 1941 and 1944	7	6	2	1	1	17
Patients treated between 1945 and 1948	8	0	0	0	1	9
Total	14	7	2	1	2	26

The difference in results here is not due to a stricter limitation of the indications but to the fact that we now always apply additional wire sutures. Angulations and shortenings were therefore eliminated entirely during the second period. All fractures treated during the first period could have been made completely stable if wire sutures had been used.

Deaths: Both deaths occurred on the day of accident because of the primary injury and the additional shock of operation. Medullary nailing should not have been done at all, or only after adequate treatment of shock.

Amputations: No amputations had to be performed.

Infection: Infection occurred in one case, eighteen days after the operation. Four months after the accident the nail was removed, and one month later a small sequestrum was removed. The wound then closed permanently and the range of knee motion at the follow-up examination was 180 to 75 degrees.

Angulation: Angulation occurred in two cases, but was less than 10 degrees in each.

Shortening: In the one case in which the result was rated as poor, the patient had shortening of six centimeters. His fracture was comminuted (this was a case analogous to the case reported in *The Journal of Bone and Joint Surgery*[1]). The shortening occurred because no additional wire sutures were used. The wound healed without infection and the knee motion was 180–70 degrees. Four patients had shortening of one centimeter or less.

Migration of the Nail: Migration occurred in two cases. In one case the nail was driven in again and in another case the nail was replaced by a thicker one. This is the more rational procedure because the migration is caused by an imperfectly fitted nail.

Unstable Bone Fixation: In seven cases bone fixation was not stable. In six of these patients, additional external cast fixation had to be applied. In all cases perfect stability could have been achieved with additional wire sutures.

Mobility of Knee Joint: In two patients, the knee joint could be flexed less than 90 degrees. Both of these were transients who could not be followed-up.

Duration of Treatment: The average stay in the Hospital was 68.3 days. The shortest stay in the Hospital was thirteen days. The average time until the patients resumed work was 279 days.

Results in Group III (Eight fractures in pathological conditions)

This group consists of one case with a solitary bone cyst, four cases of Paget's disease, two cases of fracture with tabes dorsalis, and one case with spastic luetic hemiplegia.

The case with the solitary bone cyst has been described in detail by Lorenz Böhler.* The cyst, treated only with closed medullary nailing, healed completely. Since then we have operated successfully on two other patients.

Medullary nailing has proved to be of special value in Paget's disease. In one case with typical bone changes an ordinary subtrochanteric spiral fracture occurred. After

* *Medullary Nailing of Küntscher.* pp. 242–243, Figs. 784–791. Baltimore: The Williams and Wilkins Company, 1948. *Die Technik der Knochenbruchbehandlung im Frieden und im Kriege.* Band III: *Die Marknagelung nach Küntscher.* S. 1892–1893, Abb. 3819–3826. Wien, Verlag Wilhelm Maudrich, 1944.

TABLE V

COMPLICATIONS IN GROUP II
(Twenty-six fresh open fractures)

Complications	Patients Treated between 1941 and 1944	Patients Treated between 1945 and 1948	Total
Deaths	1	1	2
Amputations	0	0	0
Infection	1	0	1
Angulation of from 5 to 10 degrees	2	0	2
Angulation of from 10 to 20 degrees	0	0	0
Shortening of from 0.5 to 2 centimeters	4	0	4
Shortening of 6 centimeters	1	0	1
Rotation	0	0	0
Migration of nail	2	0	2
Primary bone fixation not stable	7	0	7
Cast fixation	6	1	7
Less than 90 degrees of knee motion	2	0	2
Range of knee motion 180 to 90 degrees	4	1	5

closed medullary nailing the fracture was not stable and additional traction had to be applied. Angulation of 20 degrees and shortening of three centimeters occurred in spite of this. The other three cases were typical transverse fractures of Paget's disease. All were treated by closed medullary nailing. In all three instances the fractures healed completely, with perfect function, in spite of the patients' relatively high age (fifty-eight, sixty-four, and sixty-nine years). The average stay in the Hospital was only twenty-seven days and the average period before the patients resumed work was 151 days.

The results in both cases with tabes dorsalis are poor. One of these was a supracondylar fracture which was treated by closed medullary nailing. The fracture healed without complications, but tabetic arthropathy of the knee joint developed, which made arthrodesis necessary. The second case was a subtrochanteric re-fracture of the femur which did not heal in traction. After two months, open medullary nailing was done and two additional wire sutures were applied. In spite of a technically perfect operation, the fracture failed to unite and angulation occurred. Subsequently the limb shortened eleven centimeters and the nail migrated through the knee joint, without causing discomfort to the patient, appeared at the tibial tuberosity, and was then removed. This is the only patient in the entire series of ninety-five in whom the fracture failed to unite.

The last patient in this group had spastic luetic hemiplegia with a subtrochanteric fracture of the femur. Because of the spasm, union did not occur in traction; and two months later an open medullary nailing was performed. Two weeks later the wound broke open and the patient died. In this case the operation was not indicated because of the patient's general condition.

Critical Evaluation of the Results

To evaluate any method of treatment, it is necessary to know the complications which may be expected from each type of fracture.

The possible complications resulting from a femoral fracture are: (1) loss of life; (2) loss of the limb; (3) loss of the function of the limb.

Deaths: Fatalities because of pneumonia or pulmonary embolism did not occur in any of the patients in this series. We believe this record is due to the early mobilization of the patient.

TABLE VI

SUMMARY OF RESULTS IN MEDULLARY NAILING OF NINETY-FIVE FRESH FRACTURES OF THE FEMUR

Result	Group I (A) Closed Fractures Closed Nailing 1941–1942 (23 Cases)	Group I (A) Closed Fractures Closed Nailing 1943–1948 (35 Cases)	Group I (B) Closed Fractures Open Nailing (3 Cases)	Group II (A) and (B) Recent Open Fractures (26 Cases)	Group III (A) and (B) Fractures in Pathological Conditions (8 Cases)	Total (95 Cases)
Excellent	8	29	3	15	3	48
Good	8	4	0	6	1	19
Fair	5	2	0	2	1	10
Poor	2	0	0	1	2	5
Deaths	0	0	0	2	1	3
Amputation	0	0	0	0	0	0
Infection	1	0	1	1	1	4
Angulation less than 10 degrees	6	1	0	2	0	9
Angulation 10 to 20 degrees	1	0	0	0	2	3
Rotation	2	0	0	0	1	3
Shortening less than 2 centimeters	5	1	0	4	0	10
Shortening over 2 centimeters	2	0	0	1	2	5
Range of knee-joint motion 180 to 90 degrees	4	2	0	5	2	10
Range of knee-joint motion, 90 degrees and less	2	2	0	2	1	10
Fracture of the nail	0	0	0	0	0	0
Bending of nail	0	1	0	0	0	1
Migration of nail	0	0	1	1	1	3
Bone fixation not stable	15	0	1	7	2	25
Additional external fixation	10	0	1	7	2	26
Average stay in hospital (days)	76	45	73	68	56	
Average total duration of treatment (days)	205	191	238	279	309	

Death because of infection following open fractures also did not occur in our series. We believe that this can be attributed to the positive fixation of the fragments by the nailing, which decreases the chances of infection.

Of the three deaths in the ninety-five nailings, two were attributed to shock the day of the nailing and one other, which occurred two weeks after operation, to luetic brain damage. In all three cases nailing had been contra-indicated.

Causes of Loss of Function

Infection: In four cases infection occurred. In closed medullary nailing (Group I) we had one severe infection with permanent fistulae because the nail was inserted through an infected burn. Nailing in this case was not wise. In one case of open medullary nailing the nail was not inserted deeply enough and penetrated the skin. This was corrected and the wound closed in a few days. In the cases with fresh open fractures (Group II) one infection occurred. After removal of the sequestrum, the wound closed permanently. In the group of fractures in pathological conditions

TABLE VII

TIME BETWEEN ACCIDENT AND OPERATION

No. of Days	No. of Patients				
	Group I (A)	Group I (B)	Group II	Group III	Total
1	32	—	24	3	59
2 to 7	8	—	—	1	9
8 to 14	10	—	1	1	12
15 to 28	7	3	—	—	10
More than 28	1	—	1	2	4
Total	58	3	26	7*	94*

* In one case there was no accident or fracture.

(Group III) the wound broke open in one case without suppuration.

Non-Union: In the entire series, only one fracture failed to unite; this was due to tabes dorsalis.

Malalignment: In the two cases of rotation and three cases of shortening (over two centimeters) malalignment was due to faulty technique and should have been avoided.

Joint Damage: Joint damage to the injured limb can be avoided much more easily with medullary nailing, because early motion is possible. The hip and ankle joints were always free, and limitation of the knee joint was present only in cases with unstable bone fixation or in those with infection of the fracture site.

Muscle Atrophy: Muscle atrophy is almost completely avoidable, because all joints can be exercised freely after one week.

Pressure Ulcers: Pressure ulcers from plaster or traction fixation do not occur after proper medullary nailing.

Nerve Damage: Nerve damage and vascular disturbances following treatment were not observed in our series.

Complications in Medullary Nailing

In medullary nailing a number of complications are possible which do not occur with other methods. The most common complications are due to the use of too thick, too thin, too short, or too long a nail. We saw these complications only during the first two years. Since we now always measure the length and width of the medullary cavity before operation, they no longer occur.

Migration of the Nail: Migration was observed in three cases. In two of these the nail migrated proximally. The third instance occurred in a patient with tabes dorsalis; the nail

TABLE VIII

TIME OF REMOVAL OF NAIL

Length of Time Before Removal of Nail (*Months*)	Group I (A)	Group I (B)	Group II	Group III	Total
1 to 3	2	1	2	—	5
4 to 6	18	—	3	—	21
7 to 8	16	—	3	2	21
9 to 10	5	—	4	1	10
11 to 12	5	1	4	2	12
More than 12	6	—	5	2	13
Not removed	6	1	5	1	13
Total	58	3	26	8	95

penetrated the knee joint without causing discomfort. Migration is caused by minute motions at the fracture site which force the nail to come out. If this occurs a thicker nail should be substituted to inhibit motion at the fracture site.

Bending of the Nail: There was one case in this series in which bending of the nail occurred. This patient had a bad fall four months after the operation; the amount of bending was 8 degrees. We have seen some cases with medullary nailing which had been done elsewhere, in which a Küntscher nail was not employed and in which bending occurred. Schürch in Switzerland and Lauritzen in Sweden reported frequent bending of nails which were not sufficiently strong. During a recent visit to the United States the writer also heard of several cases of bending of the nail. After insertion, the nail should be fully able to stand up under weight-bearing. Therefore, only nails of the strength and design of the original Küntscher nail should be used.

Fracture of the Nail: In no cases of fresh fractures were fractures of the nails seen. In our twenty-one cases operated upon for non-union of the femur a fracture of the nail occurred twice. In both cases the nail showed a typical fatigue fracture because of the slow consolidation of the callus. In both, the fragments could be removed with a hooked nail guide through a small trochanteric incision. After insertion of a thicker nail rapid union occurred. In one case, operated upon elsewhere, we saw multiple fractures of a nail of insufficient strength.

Time of Operation: Of the fifty-eight fresh closed fractures fifty were operated on within the first two weeks.

Of twenty-six fresh open fractures twenty-four were operated upon on the first day and only two later, one on the eleventh day, with closed nailing, and one seven weeks after the fracture, with exposure of the fracture site.

Time of Removal of the Nail

We always try to remove the nail. In the cases listed in Table VIII the nail was not removed only because these patients either disappeared or refused operation.

Nails were rarely removed within the first three months, most frequently between the fourth and eighth month after operation. During the past few years it has been our practice to wait until the fracture is solidly healed,—that is, about one year. If the nail is removed too early angulation may occur. This complication has been mentioned frequently. It can be avoided if one remembers that the nail does not hasten callus formation but, like every other foreign body, delays it.

Medullary Nailing of Infected Fractures

Medullary nailing in the presence of infection is contra-indicated. After medullary nailing a local infection may spread through the entire medullary cavity. In spite of the fact that there is drainage along the nail, we think this is a very serious condition. Therefore, if infection occurs we remove the nail as soon as possible. In our experience infection ceases only after removal of the nail.

SUMMARY

At present, medullary nailing is the best treatment for transverse and short oblique closed fractures of the femur and for most open fractures of the femur, provided that the procedure is indicated and that the proper technique is employed. The main requisite is that after the operation fixation should be so firm that the patient can walk without any additional support. To ensure this, additional sutures with one-millimeter wire should always be used if an open operation is performed. The nail should be strong enough fully to replace the fractured femur in weight-bearing. Most of the complications in our cases occurred within the first two years of our use of this method because of lack of experience and because the technique had not yet been perfected.

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DISCUSSION

Medullary Nailing of Fractures of the Femur

(*Continued from page 669*)

is very simple to measure the pin at that time. You fit the pin into the bone end until you determine the correct size. You then slide a Steinmann pin down inside the canal, measuring it for length, remembering that fixation should be into cancellous bone at both ends, and, therefore, you add an inch at each end to allow for the cancellous bone and for eventual removal. I want to emphasize that proper measurement is very important. In the report you have just heard, five pins migrated. If you remember some of the pictures, the pins were too narrow to fill the canal, and in one or two cases they were too short. Some of them went obliquely across the canal. I think this accounts not only for the migrating, but also for the bending of some of the pins.

What I have just said represents difference of opinion as to detail only. The principles outlined by Dr. Street are sound. Intramedullary pinning is an excellent way of getting union and often succeeds when other methods have failed. Because of its economic and functional advantages, it is undoubtedly here to stay.

Dr. Denman C. Hucherson, Houston, Texas: The Orthopaedic Section of Jefferson Davis Hospital has employed medullary nailing of femoral-shaft fractures in fifty-two cases. We have used three types of nails: the V-shaped nail (eight cases), a U-shaped nail (five cases), and the diamond-shaped nail (thirty-nine cases).

We have discarded the V-shaped nail entirely, as in every case the nail either bent or fractured. One of our staff still prefers the U-shaped nail, but the remainder believe the diamond-shaped nail to bethe most satisfactory.

In our first eight cases we inserted the nail from the trochanter, but in three of these cases the nail became hopelessly wedged and required dramatic or near fatal measures for its removal. We have since used the retrograde technique which differs but slightly from that used by Dr. Street. We first drill out through the cortex of the trochanter with a one-quarter inch drill bit. We use a nail with an eye in each end so that it may be extracted from below if the need arises.

I was interested to hear of the use of screws combined with medullary nailing in comminuted fractures. We have not used this method, but we have employed circumferential wiring in some mildly comminuted fractures. We have not used medullary nailing in fresh compound fractures.

As Dr. Street has stated, complications are surprisingly few. There have been no infections in any of our cases. Two nails have migrated outward, but in both cases the nails were driven back under local anaesthesia without further difficulty. A painful bursitis developed over the nail in one instance.

We have considered the results to be excellent in all of our cases, with the exception of the eight in which the V-shaped nail was used.

I have enjoyed Dr. Street's paper very much, and I am most happy to find our experiences and results in such close agreement.

Dr. Dana M. Street (closing): I wish to thank Dr. vom Saal and Dr. Hucherson for their enlightening discussion. I do not concur with Dr. vom Saal's opinion that the nail has to fit tightly into the canal. As Dr. Robert Soeur pointed out, the nail traversing a curved canal impinges against the opposite walls at different levels. Also, if the nail extends far enough into the cancellous bone for secure anchorage, there can still be some looseness in the fitting of the nail at the isthmus without disturbance of healing.

POSTERIOR BONE BLOCK OF THE ANKLE FOR PARALYTIC EQUINUS

An End-Result Study *†

BY ALVIN J. INGRAM, M.D., AND JOHN M. HUNDLEY, M.D., MEMPHIS, TENNESSEE

From the Campbell Clinic and Foundation, Memphis

In 1923, Campbell [2] described the posterior bone-block operation of the ankle to correct drop-foot deformity. The technique has since been modified by Wagner [9], Gill, and others. Follow-up observation on these procedures has been done by Campbell [3, 4], Wagner [10], Wheeldon and Clark, Branch, and Carrell and Childress. None of these authors, however, has reported the long-term results of these operations in a series large enough to justify definite conclusions concerning their relative merits. The purpose of this study is to evaluate critically the late results of the posterior bone block of the ankle; and, on the basis of the cases studied, to draw conclusions concerning the indications, the contraindications, the results, and the complications of the operation.

METHOD OF STUDY

At the time of this study, 477 patients who had had bone-block operations done before September 1943 were requested to return for examination. Seventy-nine patients, eleven with bilateral bone blocks, responded. Of the remaining 398, 133 were followed more than five years. A study of the clinical notes and the roentgenograms allowed a fairly accurate grouping and did not lead the authors to believe that there would have been any significant changes in the statistics had more returned. All of those who returned for examination are included in this study, and the cases reported herewith were all seen personally by one or both of the authors within the past eighteen months.

The patients were questioned concerning the following points: age; sex; race; occupation; the location, character, and severity of any pain in the foot or ankle; the patient's endurance; whether or not braces had been used; whether or not the patient was satisfied with the result; and whether or not there were any complaints.

The clinical examination included the following: A muscle test was done on the extremity concerned; the lengths of the extremities were measured; the presence of other musculoskeletal disabilities was noted; the gait was analyzed, especially as to steppage; the range of motion of the foot on the leg was noted; the ankle was palpated for crepitation; and the end result of the foot stabilization was evaluated.

In each case, three roentgenograms were made,—the routine anteroposterior, a lateral view in forced plantar flexion, and a lateral view in forced dorsiflexion. To determine the range of motion of the foot on the leg and of the stabilized mass (usually the talus, calcaneus, cuboid, and navicular) on the tibia, the lateral roentgenograms were measured as follows (Fig. 1): Line *a* represents the axis of the tibia; line *b* connects two fixed points in the stabilized posterior portion of the foot; line *c* represents the plane of the sole of the foot and connects the plantar surfaces of the calcaneus and the first metatarsal head. The numerical difference between angles $A\ O\ C$ and $A'\ O'\ C'$ represents the total movement of the foot on the leg. The difference between angles $A\ X\ B$ and $A'\ X'\ B'$ is the amount of motion in the ankle. The amount of motion in the unstabilized portion of the foot is obtained by subtracting the degrees of ankle-joint motion from the total degrees of motion of the foot on the leg.

This method of measurement was used in all cases; and, while there is a definite

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 14, 1950.

† Received for publication February 3, 1951.

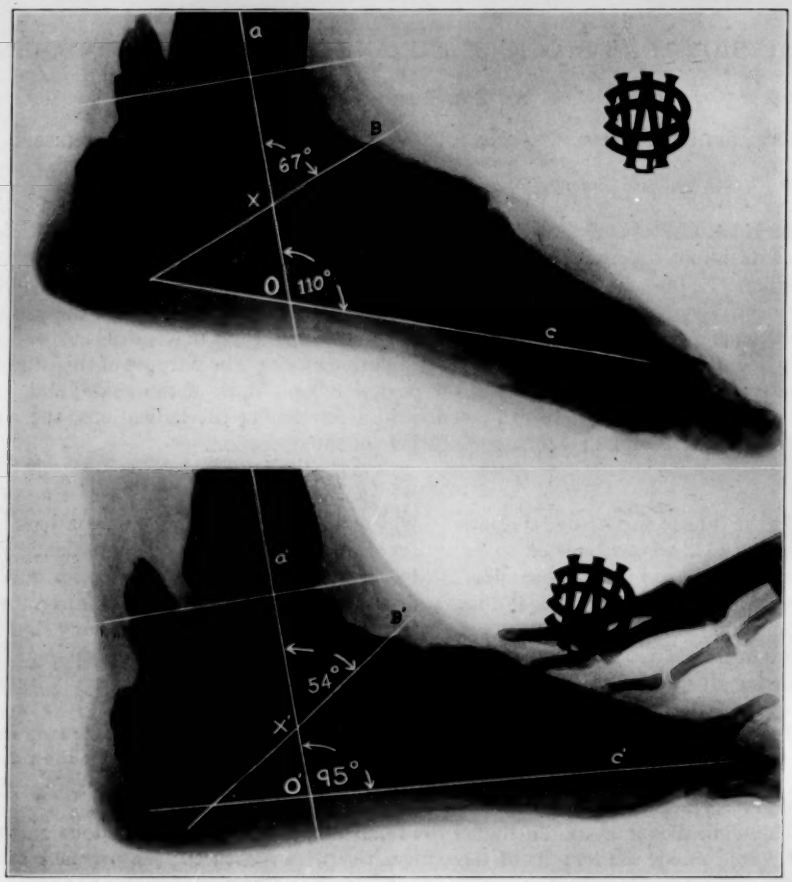

FIG. 1

Measurement of Motion

Angle *A O C* (110 degrees) is maximum plantar flexion and *A' O' C'* (95 degrees) is maximum dorsiflexion of the foot on the leg. The range of motion is 15 degrees (110 degrees minus 95 degrees). The amount of motion in the tibiotalar joint (13 degrees) is determined by subtracting angle *A' X' B'* (54 degrees) from angle *A X B*. The unstabilized joints of the foot contribute the remaining degrees of motion. (15 degrees minus 13 degrees = 2 degrees.)

margin of error present, the method is not only objective but is also the most satisfactory technique described to date.

The roentgenograms were carefully studied for the presence or absence of hypertrophic changes and changes due to aseptic necrosis. The type of procedure was also studied,—that is, whether or not the bone block was accomplished by the massive posterior block, the small postero-inferior block popularized by Wagner, or by the method of Gill.

GENERAL OBSERVATIONS

A total of seventy-nine patients returned for examination. Of this group, eleven had had bilateral bone-block operations done, while sixty-eight had had unilateral. The total number of ankles examined, then, was ninety. There were forty-three females and thirty-six males.

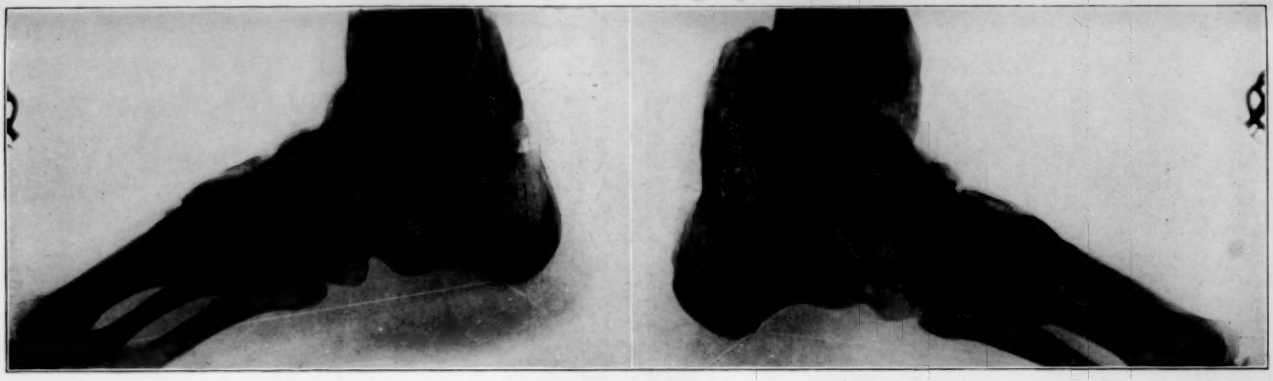

FIG. 2-A

FIG. 2-B

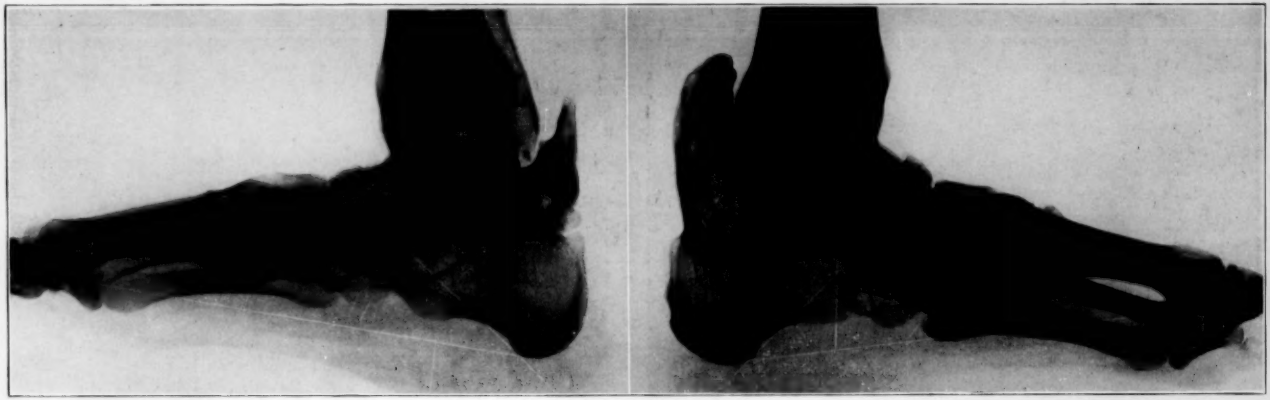

FIG. 2-C

FIG. 2-D

Excellent result in a male, thirty-one years old, followed twenty-three years after bone block was done on both feet. There remained 23 degrees of motion in the right ankle and 15 degrees of motion in the left.

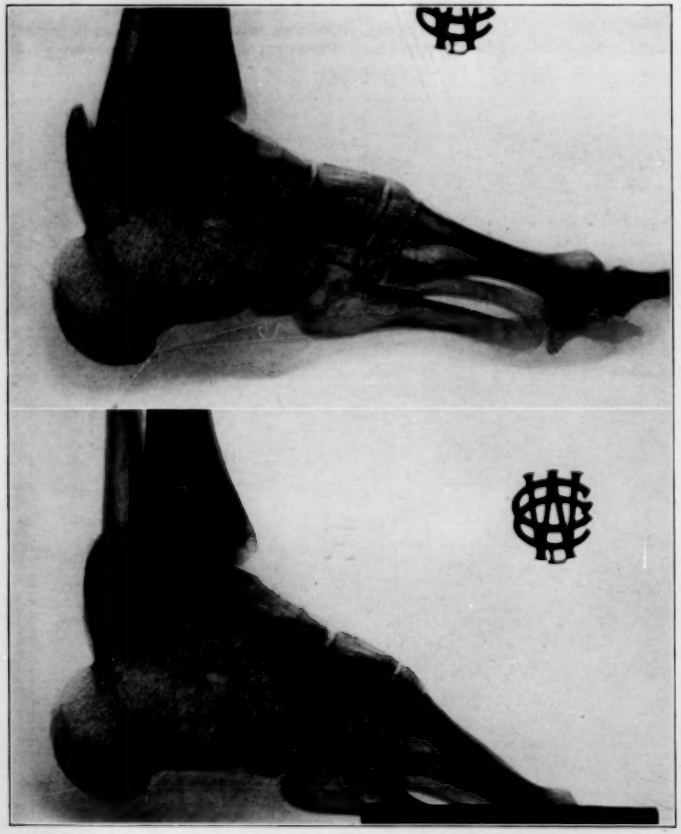

FIG. 3

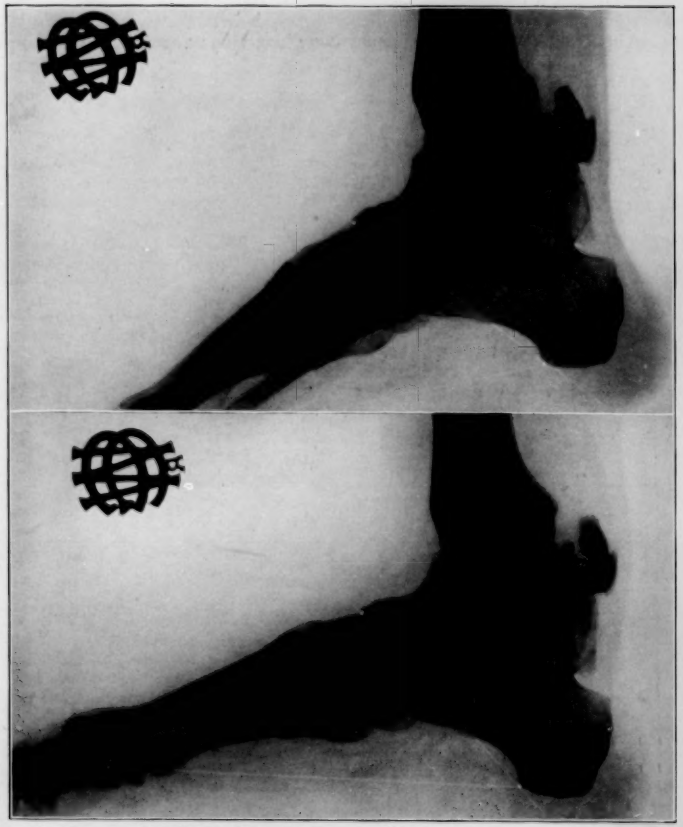

FIG. 4

Fig. 3: An excellent result in a housewife, forty-three years old, twenty years after operation. There remains 24 degrees of motion in the ankle. Note the upward inclination of the anterior articular margin of the tibia, possibly resulting from accidental anterior epiphyseal arrest.

Fig. 4: An excellent result in a housewife, thirty-eight years old, followed eighteen years after the Gill type of bone block. There is measurable motion of 17 degrees in the ankle joint.

Fig. 4: An excellent result in a housewife, thirty-eight years old, followed eighteen years after the Gill type of bone block. There is measurable motion of 17 degrees in the ankle joint.

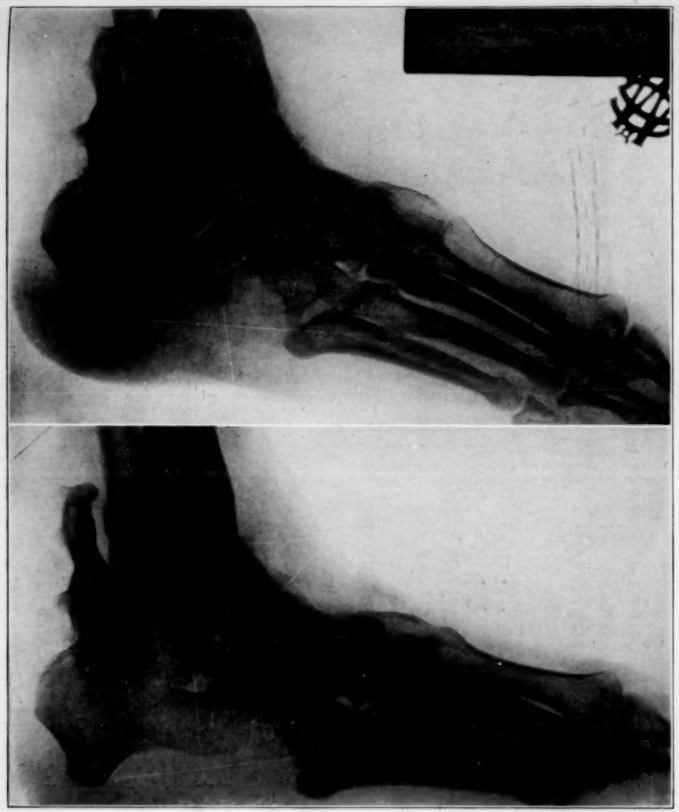

FIG. 5

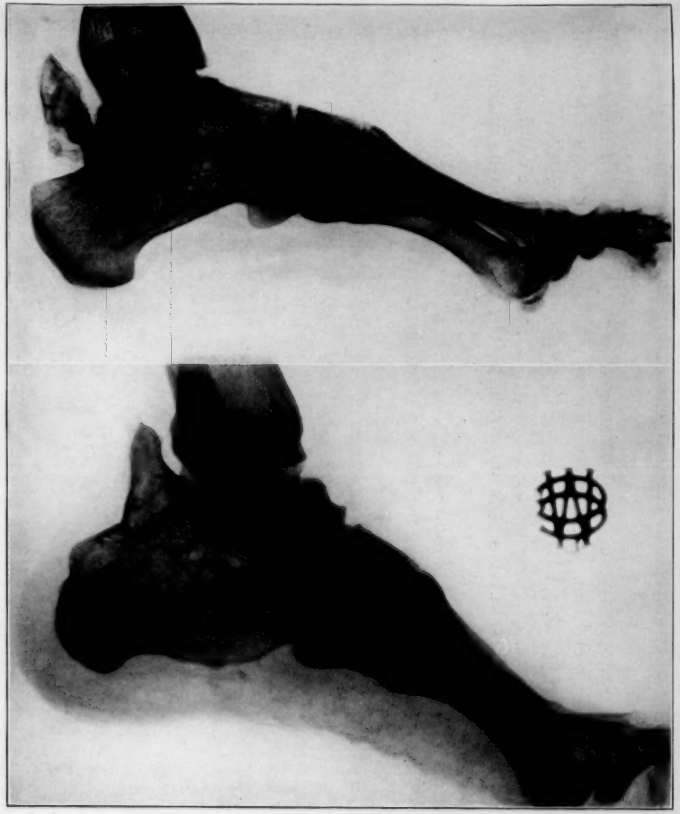

FIG. 6

Fig. 5: Moderate arthritic changes between the anterior tibial articular margin and the talus in a schoolteacher, forty years old, operated upon twenty-five years previously. The foot appears to pivot or hinge upon this point.

Fig. 6: The upper view demonstrates mild arthritic changes at the anterior joint level, sixteen years since operation. The bone block is fragmented, free, and is not effective. The result is poor.

The ankle shown in the lower roentgenogram demonstrates moderate arthritic changes in a farmer, thirty-three years old, who has been followed for twenty-two years.

The cause of the original drop-foot deformity in the ninety ankles studied was as follows: poliomyelitis, eighty-six; spastic cerebral palsy, two; athetoid cerebral palsy, one; peripheral-nerve injury, one.

The duration of postoperative observation ranged from five years to twenty-seven years, the average being eighteen years. Sixty per cent. of the patients were followed longer than twenty years (Table VI).

Eleven patients were either wearing a brace when examined or, in the opinion of the examiner, their condition would have been improved by the use of one. One patient required high-top shoes for daily use.

Thirteen patients complained of mild pain in the foot or the ankle on weather changes, and four had mild pain after excessive use of the extremity. No patient was disabled by pain, and none had moderate or severe pain.

In the great majority of cases, the endurance of the ankle was quite satisfactory,—the patients examined were more disabled by associated disabilities than by the limited motion of the ankle. In six, the endurance of the ankle was poor.

The duration of drop-foot prior to the operation ranged from between two years and twenty-six years,—the average was ten years.

The present age ranged from sixteen years to forty-nine years,—the average was thirty-three years.

The present occupational status of the patients represents a cross section of our civilian economy, ranging from a farm laborer to an opera singer.

CRITERIA

Excellent

1. No pain;
2. No significant arthritis;
3. The entire foot does not plantar-flex beyond 105 degrees and can be dorsiflexed to 90 degrees or more;
4. There must be 10 degrees or more of motion in the ankle. The average was 12 degrees;
5. No support and no steppage gait.

Good

1. No pain on ordinary activities; there may be slight pain after excessive activity;
2. Mild arthritis, but good endurance and no pain;
3. Foot blocks at 115 degrees or less;
4. There must be 10 degrees or more of motion in the ankle. The average was 13 degrees;
5. No support and no steppage gait.

Fair

1. No pain on ordinary activity, but slight pain after excessive activity;
2. There may be mild to moderate arthritis, but good endurance and no pain;
3. The foot must be blocked at 120 degrees or less;
4. Less than 10 degrees of motion, but ankylosis not demonstrated. The average was 10 degrees;
5. No support.

Poor

1. Pain;
2. Severe arthritis, or moderate arthritis with pain;
3. Foot is blocked beyond 120 degrees;
4. Fibrous or bony ankylosis;
5. A brace may be required.

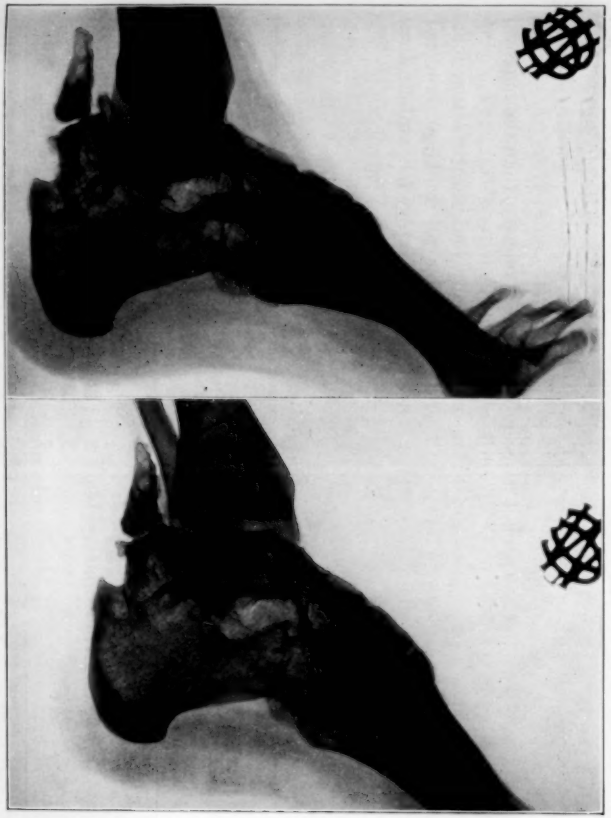

FIG. 7

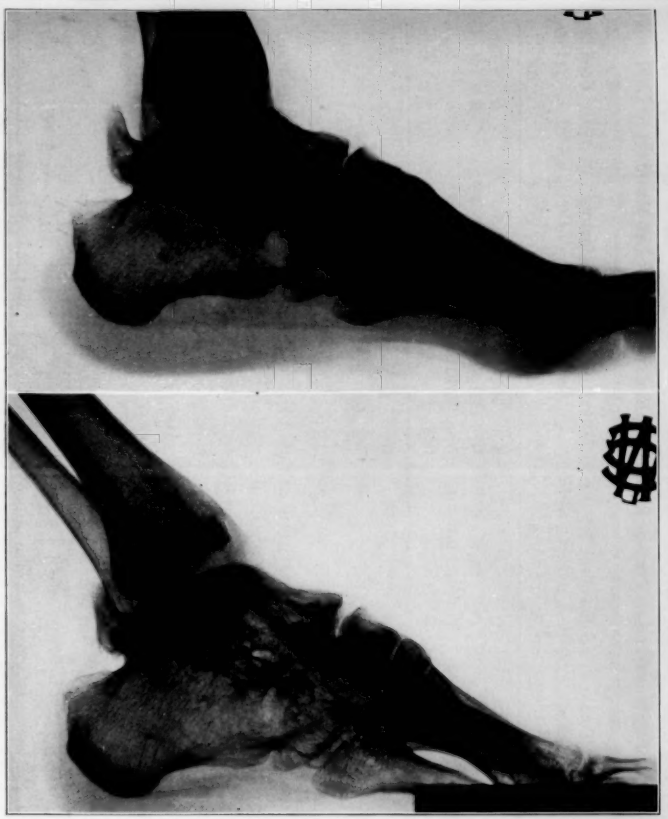

FIG. 8

Fig. 7: A poor result in a housewife, twenty-four years old, operated upon fifteen years previously for a dynamic drop-foot. The foot has been stabilized in equinus at the mid-tarsal joint. Excessive plantar flexion (126 degrees) is present.

Fig. 8: A poor result eleven years after operation, because of excessive plantar flexion (133 degrees). Note mild arthritic changes between bone block and posterior margin of tibia.

TABLE I

AGE OF PATIENT AT THE TIME OF SURGERY IN RELATION TO THE END RESULTS

Age Group (Years)	Total No. in Group	Excellent		Good		Satisfactory		Poor	
		No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
0 to 9	11	0		4	36.4	2	18.1	5	45.5
10 to 14	38	6	15.8	9	23.8	15	39.4	8	21.1
15 to 19	25	8	32.0	5	20.0	6	24.0	6	24.0
Over 20	16	6	37.5	0		6	37.5	4	25.0
Total	90	20	22.2	18	20.0	29	32.2	23	25.6

RESULTS

An attempt was made to determine which type of bone-block procedure was most effective in this series; but, because of the many combinations in this group, this was impossible. It is our impression, however, that the small intra-articular block which impinges

TABLE II

THE EXTENT AND SEVERITY OF THE PARALYSIS IN RELATION TO THE END RESULTS

Type of Paralysis	Total No. in Group	Excellent		Good		Satisfactory		Poor	
		No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Dynamic	28	6	21.5	5	17.8	8	28.6	9	32.0
Balanced	12	2	16.7	7	58.3	3	25.0	0	
Flail	47	12	25.6	5	10.6	17	36.2	13	27.6
Total	87	20	23.0	17	19.5	28	32.2	22	25.2

on the posterior-inferior lip of the tibia is more desirable, mechanically, than the massive block designed to impinge on the posterior surface of the tibia.

Sixteen of the ninety patients in this series, or 18 per cent., had unsatisfactory foot stabilization. This group is contemporary with, and comparable to, the large series reported by Crego and McCarroll in which 20 per cent. had unsatisfactory foot stabilization secondary to vicious muscle pull.

TABLE III

HYPERTROPHIC ARTHRITIS: FORTY CASES (44.4 PER CENT.)

Follow-up (Years)	Total No. in Group	Mild		Moderate		Severe		Total with Hypertrophic Arthritis	
		No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
0 to 9	15	2	13.3	0		0		2	13.3
10 to 14	12	1	8.3	1	8.3	0		2	16.6
15 to 19	9	4	44.4	3	33.3	0		7	77.7
20 to 24	34	9	26.4	8	23.5	1	2.9	18	52.8
Over 25	20	3	15.0	7	35.0	1	5.0	11	55.0
Total	90	19	21.1	19	21.1	2	2.2	40	44.4

1. *Age at the Time of Surgery* (Table I): The poorest results (45.5 per cent.) were obtained in patients operated upon before ten years of age. The best results were obtained in those between the ages of ten and fifteen years when operated upon, and most of the patients were in this age group at the time of surgery.

2. *Extent and Severity of the Paralysis* (Table II): In feet paralyzed as the result of poliomyelitis, a study was made to correlate the balance of power in the remaining muscles acting on the foot with the result. Three arbitrary categories were established. The dynamic drop-foot is characterized by plantar flexor muscles two or more grades stronger than the dorsiflexors; a balanced drop-foot is one in which there is a discrepancy of less than two grades; and a flail foot is one in which there is little or no power in either group. The best results were obtained in that small group of patients with balanced drop-foot deformities. In general, the failures in those patients with dynamic drop feet were associated with an excessive range of plantar flexion or a recurrence of the deformity. On the other hand, failures in the flail drop-foot group were associated with ankylosis of the ankle, in the majority of cases.

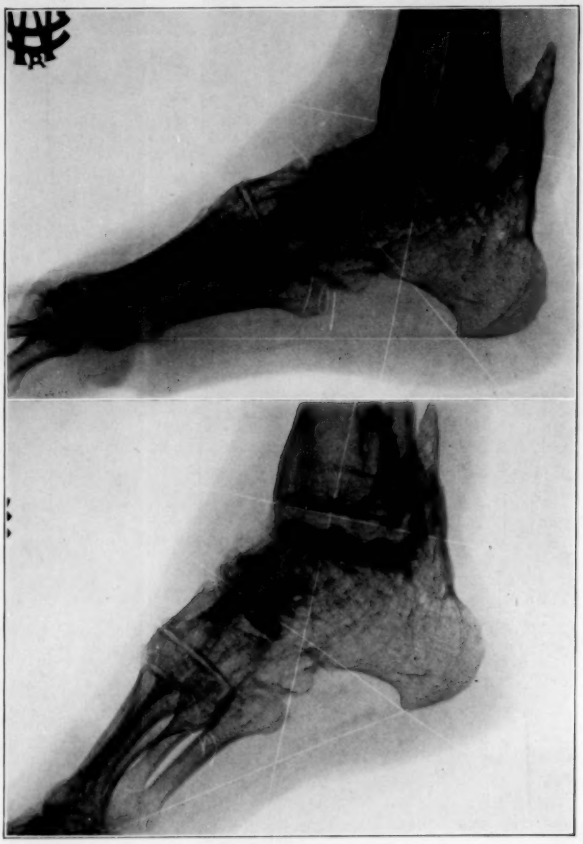

FIG. 9

A poor result, due to aseptic necrosis and flattening of the talus. Patient was a forty-year-old housewife, observed for twenty-three years.

3. *Hypertrophic Arthritis* (Table III, Figs. 5 and 6): All roentgenograms were carefully studied for the presence of hypertrophic arthritic changes, and they were graded arbitrarily as mild, moderate, or severe. They were noted in forty of the ninety cases, or 44.4 per cent. Two patients had severe arthritic changes, associated with flattening of the body of the talus from aseptic necrosis. Nineteen patients demonstrated mild arthritic changes, probably more directly caused by the foot stabilization than by the bone block itself. Arthrodesis of the subtalar, talonavicular, and calcaneocuboid joints unquestionably subjects the ankle joint proper to many minor medial, lateral, and rotatory stresses which would be dissipated by normal intertarsal articulations. At the present time, a study is being made to elucidate this point.

4. *Aseptic Necrosis* (Table IV, Figs. 9 and 10): Sclerosis and flattening of the body of the talus were noted in twenty-four of the ninety cases, or 26.7 per cent. of the cases. This was interpreted as being the end result of aseptic necrosis of the body of the talus, although

FIG. 10-A

FIG. 10-B

FIG. 10-C

FIG. 10-D

Showing result twenty years after bone-block operation in a filling-station attendant, thirty-one years old. Mild arthritic changes and mild flattening of the talus are evident; otherwise, the result is good.

TABLE IV

FLATTENING OF THE TALUS FROM ASEPTIC NECROSIS
TWENTY-FOUR CASES (26.7 PER CENT.)

Follow-up (*Years*)	Total No. in Group	Mild		Moderate		Severe		Total	
		No.	*Per Cent.*	*No.*	*Per Cent.*	*No.*	*Per Cent.*	*No.*	*Per Cent.*
0 to 9	15	1	6.6	0		0		1	6.6
10 to 14	12	2	16.6	0		0		2	16.6
15 to 19	9	1	11.1	2	22.2	0		3	33.3
20 to 24	34	3	8.8	7	20.5	0		10	29.3
Over 25	20	1	5.0	5	25.0	2	10.0	8	40.0
Total	90	8	8.8	14	15.5	2	2.2	24	26.7

milder changes of this character may be confused with mild hypertrophic changes. In all probability, the changes due to aseptic necrosis are caused by interference with the blood supply to the talus, which comes largely from the vessels in the tarsal sinus. For this reason, a fairly high percentage of patients undergoing the Hoke triple arthrodesis or the Lambrinudi procedures would probably demonstrate similar changes, if followed over a comparable period.

TABLE V

RANGE OF MOTION CORRELATED WITH THE RESULT

Result	Ankle		Other Joints		Total
	Average (*Degrees*)	Range (*Degrees*)	Average (*Degrees*)	Range (*Degrees*)	Average (*Degrees*)
Excellent	12.0	(10 to 24)	4.0	(0 to 13)	16
Good	13.0	(10 to 22)	4.0	(0 to 22)	17
Satisfactory	10.5	(5 to 38)	5.5	(0 to 35)	16
Poor	21.0	(9 to 29)	8.0	(0 to 15)	29

From these last two studies, it is evident that the longer the period of observation, the more apparent are the hypertrophic and degenerative changes on the roentgenogram. It should be re-emphasized, however, that in none of the patients studied was pain an important factor, and in only one of the cases with roentgenographic evidence of arthritis was the patient's endurance in the ankle significantly limited.

5. *Range of Motion* (Table V, Figs. 7 and 8): In patients with a satisfactory result, there was usually approximately seventeen degrees' motion of the foot on the leg. Three fourths of this range of motion was actually in the talotibial joint and one fourth was

TABLE VI

RESULT CORRELATED WITH FOLLOW-UP PERIOD

Follow-up Period (*Years*)	No.	Excellent		Good		Satisfactory		Poor	
		No.	*Per Cent.*	*No.*	*Per Cent.*	*No.*	*Per Cent.*	*No.*	*Per Cent.*
5 to 9	15	5	33.3	3	20.0	2	13.3	5	33.3
10 to 14	12	2	16.6	2	16.6	6	50.0	2	16.6
15 to 19	9	2	22.2	3	33.3	2	22.2	2	22.2
20 to 24	34 (60 per cent.)	8	23.5	9	26.5	9	26.5	8	23.5
Over 25	20 (60 per cent.)	3	15.0	1	5.0	10	50.0	6	30.0

present in the remaining intertarsal and tarsometatarsal joints. In those patients with unsatisfactory results, there was usually either a bony or fibrous ankylosis of the ankle or an excessive range of motion, allowing plantar flexion beyond 120 degrees.

6. *Result Correlated with the Follow-up Period* (Table VI): The highest percentage of poor results was in those patients followed for between five and ten years and in those observed for more than twenty-five years. The highest incidence of satisfactory results was in those patients observed for between ten and fifteen years after surgery. Some deterioration in the results was noted in the group followed more than fifteen years.

CONCLUSIONS

1. Posterior bone block of the ankle is productive of permanent satisfactory correction of drop-foot deformity in a high percentage of cases.

2. If possible, the operation should be performed when the patient is between ten and twenty years of age.

3. It should be done in conjunction with arthrodesis of the talonavicular, subtalar, and calcaneocuboid joints. Care should be exercised to preserve the circulation of the talus.

4. Tendon transference should be done, when possible, after the principles laid down by Peabody and Crego and McCarroll. Better results are obtained when there is a balance of power between dorsiflexors and plantar flexors of the ankle.

5. We prefer an intra-articular block, placed immediately posterior to the talus, so that it will impinge on the posterior lip of the tibia.

6. This operation should be reserved for those patients who can be rendered brace-free thereby.

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DISCUSSION

Dr. Brandon Carrell, Dallas, Texas: This paper was of particular interest to me, since we practically stopped doing posterior bone blocks in the Texas Scottish Rite Hospital for Crippled Children ten years ago. In the *Southern Medical Journal* of May 1939 (Vol. 32) my father and Dr. H. M. Childress reported 140 cases of posterior bone block done in the preceding ten years. The results, based on essentially the same criteria as those set forth in this paper, but with a shorter period of follow-up, were quite similar,—namely, 79 per cent. satisfactory and 21 per cent. unsatisfactory. We had two principal objections to the procedure,—that it tends to become gradually less effective with strong unopposed plantar flexors and that, when combined with triple arthrodesis, it was a rather difficult technical procedure for our residents.

In the search for a more suitable method of overcoming foot-drop, it was decided to try a series of stabilizations of the Lambrinudi type. In the past ten years, we have done ninety-eight Lambrinudi stabilizations and only six posterior bone blocks in a total of 644 triple arthrodeses. A follow-up study has not yet been completed, but I have recently gone over all of the charts. I am better satisfied with these than with bone blocks, although the percentage of failure is running about the same and for the same reason, chiefly in the so-called dynamic group. It is a much simpler procedure, being little more difficult than the usual triple arthrodesis and, when done correctly, definitely limits plantar flexion.

Even in the failures, a bone block can later be done if indicated, decreasing the percentage of failure. Although I do not particularly favor bone blocks as an initial procedure, I would like to compliment the authors on the thoroughness of their study and upon the excellent manner in which the material was presented.

Dr. John Royal Moore, Philadelphia, Pennsylvania: Dr. Campbell began his bone-block operations in 1921. He was undoubtedly stimulated by a report from a committee appointed by The American Orthopaedic Association to investigate the different operations for drop-foot. This Committee, after studying the innumerable procedures available at that time, including tendo achillis lengthening, astra galectomy, panastragalar arthrodesis, triple arthrodesis, and muscle transplantation, declared that no operation existed at that time which could be recommended to take care of drop-foot. Dr. Campbell submitted his first report on the bone-block operation for drop-foot in 1929 at the joint meeting of The American Orthopaedic Association and The British Orthopaedic Association held in the British Isles. He submitted a follow-up of 142 cases, seventy-six children and sixty-six adults, and reported that 92 per cent. of the bone-block operations on children were successful and 90 per cent. of those on adults were successful. He explicitly stated that there were no cases of arthritis in the group and no mention was made of aseptic necrosis. The results and conclusions presented by the present authors differ fairly widely from those found by Dr. Campbell in his earlier paper. However, this can be partly explained by the fact that the follow-up of the present authors amounts to twenty years or more, whereas Dr. Campbell's follow-up extended from 1921 to 1929 (eight years).

From a careful analysis of the present paper, I am forced to conclude that one can expect a successful bone block,—that is, one free from pain and one that has a stop at 110 degrees, one that does not have aseptic necrosis and one that does not cause rapid fatigue, in approximately one out of five cases. Furthermore, it is quite evident that the bone block should not be done in flail feet or in the so-called dynamic foot (a foot of a person with strong calf muscles). It seems very important indeed to combine muscle balancing with the bone block whenever possible. This is quite far from Dr. Campbell's early conclusions, and I think it shows beyond question the value of the long follow-up.

I think the authors of the present paper should not feel discouraged concerning the conclusions which I have drawn. They have presented their facts thoroughly and honestly. The bone block still is the best procedure for a paralytic drop-foot.

Dr. Alvin J. Ingram (closing): In answer to Dr. Carrell, I must state that, of necessity, the criteria for results were arbitrarily established, and the cases were studied as objectively as possible. Our hope is that this study will provide a yardstick for the comparison and evaluation of operations designed to correct paralytic equinus deformities. Thus far, there has not been reported a comparable series of Lambrinudi procedures or Hoke triple arthrodeses in order to allow a true comparison of results.

In answer to some of Dr. Moore's remarks concerning the type of the bone block done, we believe that the fundamental mechanical principle is the same, whether you use a massive posterior block or a small intra-articular block. The chief reason we do not prefer the massive block is that it seems to result in a higher incidence of ankylosis.

As for the types of stabilization which were done, we mentioned that all of these patients, except one, had a triple arthrodesis, usually of the Hoke variety. The stabilizations are comparable in every respect to a large series reported in 1939 by Crego and McCarroll, in which the results were unsatisfactory in 20 per cent. of their cases. In this series 17 per cent. were unsatisfactory, and this is of no statistical significance.

As far as foot-drop in the fore part of the foot is concerned, we have mentioned that, and I showed a case which illustrated a poor result secondary to foot-drop of the fore part of the foot. I can hardly see how, with the figures we have presented, a person can draw the conclusion that the operation would be effective in only 20 per cent. of the patients. There was no way in which the cases could be broken down to show anything like 80 per cent. of poor results.

In conclusion, I would like to say that there are two matters pointed up by this study which I think would bear investigation in the future. One is the incidence of aseptic necrosis following the stabilization of the foot. No study has ever been made, which I know of, in a series of cases followed over a sufficiently long time to demonstrate the incidence of this complication. The second thing is the presence of arthritis. It is our firm belief that a considerable number of the hypertrophic arthritic changes mentioned are caused by the triple arthrodesis.

TRIPHALANGEAL THUMB

BY HENRY MILCH, M.D., NEW YORK, N. Y.

Triphalangism of the thumb would seem to be exceedingly uncommon and the references to it in the literature are correspondingly few. Because of this, the extra phalanx has occasionally been considered to be an exostosis and is most commonly given the misnomer of an "accessory ossicle". In the American literature, Haas appears to have been the first to direct attention to this anomaly. Noting the earlier reports of other observers, Haas added the records of three families, in which one or more individuals had thumbs with three joints. Lapidus and his associates have submitted two communications and Müller has written extensively on the subject.

Several different theories have been advanced to explain this anomaly. Haas has expressed the opinion that ". . . in the normal, developing thumb the extra phalanx is assimilated by the distal phalanx". From this it would seem that the appearance of the third phalanx is evidence of an arrest in normal development. This is unlikely since, if it were so, the condition would be more commonly seen.

Lapidus and his coworkers categorically reject this opinion in favor of the belief that "triphalangism of the thumb may be only an incomplete development of the distal

FIG. 1

Case 1. C. S. Amputations of the fingers of the left hand are traumatic. Both thumbs present congenital anomalies. The left thumb shows an interposed small bone articulating proximally with the extended first phalanx and distally with the oblique surface of the base of the distal phalanx. The right thumb presents bifidism of the proximal phalanx. Each of the bifid elements presents a similar ossicle between the proximal and the distal phalanx. The ulnar half of the bifid thumb is seen in an anteroposterior view and shows the typical lateral curvature. The radial half is seen in a lateral view as if it had rotated 90 degrees. In this case, the base of the intercalated ossicle is directed toward the ulna.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. D. R. Roentgenogram, made before the operation, reveals interposed bony ossicle with its base directed toward the radial side of the finger.

Fig. 2-B: Roentgenogram, made four months after the operation, shows that the ossicle has been removed. The curvature, indicated by the shadow of the overlying skin, is still present because of the persistent wedging of the epiphysis of the distal phalanx. This tends to disappear with the normal growth of the epiphysis.

part of one of the two nail phalanges of the bifid thumb" and that "the additional phalanx of the triphalangeal thumb is not a true middle phalanx similar to that of the lesser fingers, but a remnant of the base of one of the phalanges of a bifid thumb". Haas himself noted that "there was a peculiar duck-bill appearance of the end phalanx in several patients, a separation of the extra phalanx and other evidences of attempts at division".

Without undertaking any critical analysis of the various theories of causation, it would seem that the theory of phalangeal bifidism offers a more satisfying and consistent explanation of the condition than does the earlier theory of developmental arrest.

CASE 1. C. S., a Negro, aged thirty-seven years, first came to the out-patient department of the Hospital for Joint Diseases in January 1943, complaining of pain in the back. During the course of a routine examination, anomalies of both hands were noted.

It appeared that, a number of years before, the patient had suffered an injury to his left hand, as a result of which the terminal phalanges of the second and fourth fingers and the distal two phalanges of the middle finger had been amputated.

Interest was primarily centered upon the thumbs,—the right thumb was definitely bifid. Though no careful examination of his genealogy was made, it was noted that other members of his family showed similar anomalous thumb formations.

The patient had good grasping power and good motion in both thumbs, and there was no claw effect between the two parts of the right thumb. The explanation of this interesting anomaly was seen in the roentgenogram (Fig. 1).

The metacarpal head of the right thumb was shown to be irregular, somewhat wedge-shaped, and articulated with the bifid proximal phalanges which were united at their proximal extremity. From this point, the bifid phalanges diverged almost at right angles. On an anteroposterior view, the ulnar portion of the bifid proximal phalanx was seen, while, in the lateral view, the radial portion of the bifid phalanx was seen as though it had been externally rotated 90 degrees. Placed between what appeared to be normal distal phalanges were wedge-shaped ossicles, the bases of which appeared to be mainly directed toward the ulnar side. In the radial

element, the intercalated bone was seen in the lateral view and its articulation with the terminal phalanx was overlapped by the base of the terminal phalanx, so that the two appeared to be fused. The terminal phalanges themselves were quite normal in size and contour.

On the left hand, the interposed bone, lying on the volar aspect of the thumb, led to hyperextension rather than to a lateral deviation of the distal phalanx. The ossicle appeared wedge-shaped, and the articular surface of the distal phalanx had been correspondingly angulated. Because it did not interfere with his function in the slightest, the patient refused any surgical intervention. The curvature which this accessory ossicle caused did not seem to impair the function of the thumb for ordinary purposes.

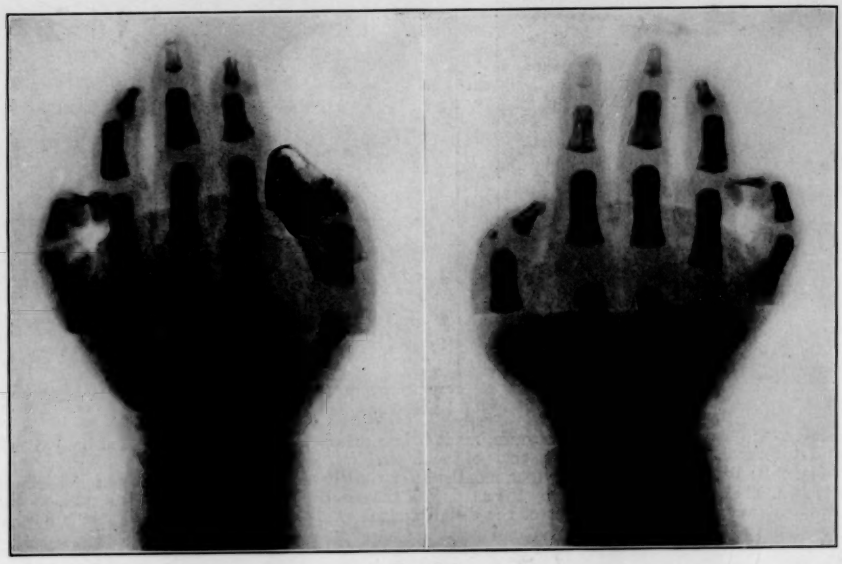

FIG. 3-A

Case 3. S. R. Roentgenograms of both hands made shortly after birth. The earliest formation of the accessory ossicle is to be noted on the radial side of both thumbs between the proximal and distal phalanges.

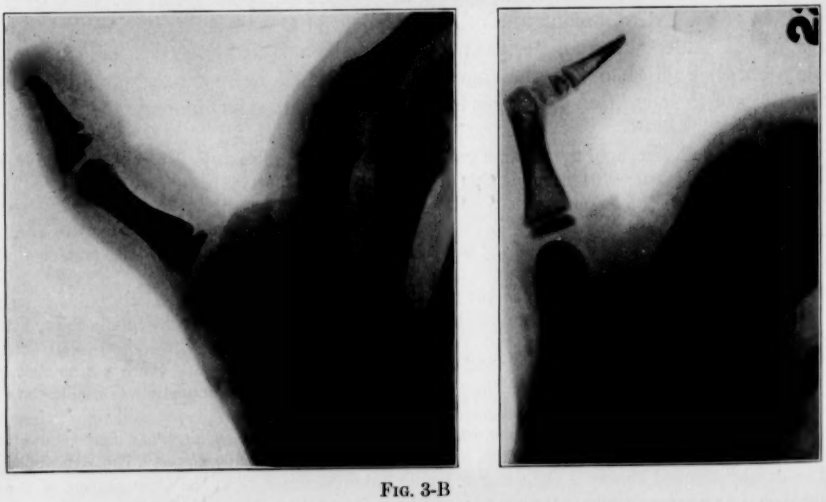

FIG. 3-B

Case 3. Roentgenograms of the right thumb at the age of five and one-half years. The ossicle has become larger. It is to be observed that flexion occurs between the ossicle and the head of the proximal phalanx.

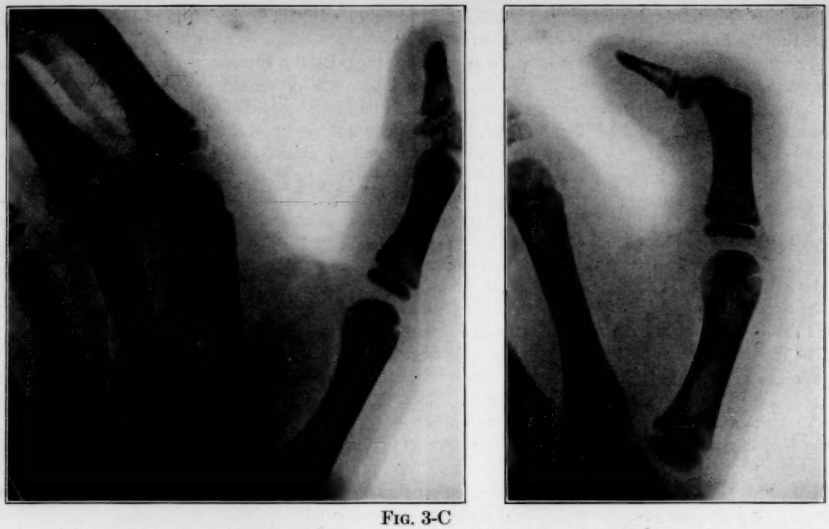

FIG. 3-C

Roentgenograms of left hand show similarity to right.

Considering the fact that function may be seriously impaired, correction of the deformity by surgery in adult life is definitely contra-indicated. In children, the situation is entirely different; and it is then, if at all, that the correction of the deformity is possible without jeopardy to the function of the thumb. These deformities are occasionally seen in early childhood, when the importunities of a solicitous mother to prevent further curvature of the thumbs may present a real clinical problem, and surgical measures may be taken.

CASE 2. D. R., aged three, was admitted to the Hospital on February 2, 1949, suffering from a number of deformities. At birth a fracture of the right clavicle was incurred. Within a few days the mother noted that the right thumb was crooked, the left thumb was stiff, and there was webbing of the third and fourth toes of the left foot. During the preceding three years, the mother had noted that the curvature of the thumb was becoming progressively more marked.

Examination of the left thumb disclosed a limitation of flexion at the metacarpophalangeal joint, which was thought to be due to a stenosing tendovaginitis. On the right hand, a marked ulnar curvature of the right thumb in the region of the interphalangeal joint was noted. The axis of the distal phalanx made an angle of 30 degrees with the axis of the proximal phalanx. Extension was limited at 170 degrees, and flexion at 90 degrees. The roentgenograms revealed the typical interposition of a small wedge-shaped bony mass between the proximal and distal phalanges of the thumb. The base was directed toward the radial aspect of the thumb, and there was beginning pressure atrophy of the epiphysis of the distal phalanx (Fig. 2-A).

In view of the progressive nature of the deformity, operative removal of the bony mass was thought justifiable. On February 7, 1949, under general anaesthesia, a longitudinal, dorsolateral incision was made over the interphalangeal joint. When the joint had been opened, the small bony mass was found, wedged between the joint surfaces, but having no muscular attachment whatsoever. The mass was easily dislocated from the interarticular space.

Because of the laxity of the joint, a small splint was applied to maintain the position until the joint laxity had been overcome. Healing was uneventful. When seen again in June 1949, the child had completely normal use of the thumb. There was no limitation of motion and no loss of power in the thumb. There was no abnormal mobility of the thumb. Except for the slight curvature which persisted, and was believed to be due to the pressure atrophy of the digital epiphysis, the roentgenographic appearance after the operation was normal (Fig. 2-B).

This patient was seen again in March 1950, for follow-up purposes. The laxity had almost disappeared, but the curvature still persisted.

CASE 3. S. R., aged five and one half, was first seen September 1948. The mother noted a curvature of both thumbs at birth and roentgenograms (Fig. 3-A) showed a small accessory center of ossification on the radial side of the thumbs between the first and second phalanges. The mother was advised that nothing

could be done about this. However, the continuing and progressive ulnar deviation of the distal phalanges of both thumbs had again begun to worry the mother.

The curvature of the thumbs was quite apparent; otherwise the thumbs seemed to be quite normal. There was no limitation of, nor abnormality in, motion. There was no change in either the sensation or the motor power of the thumb. The roentgenograms of both hands (Figs. 3-B and 3-C), with the thumbs extended and then flexed, disclosed the progressive curvature and the increasing size of the ossicle. The triangular ossicle was definitely independent both of the normal phalanx and of the epiphysis of the distal phalanx which it had somewhat deformed by pressure. It was observed, however, that the ossicle and the distal phalanx moved in unison and that flexion and extension occurred between the ossicle and the metacarpal head.

Operation was advised but was refused by the mother.

CASE 4. A. J., aged seven, was first seen in the out-patient department in November 1948, because of the "crookedness" of both thumbs. There was no familial history of any similar deformity. The child had normal use of his thumbs, and it was solely for the correction of the curvature that relief was sought.

The roentgenograms of both hands (Fig. 4-A) revealed that the curvature was due to the existence of small wedge-shaped bones lying between the heads of the proximal phalanges and the epiphyses of the distal phalanges. The base of the wedge, directed toward the ulna, caused a radial deviation of the distal phalanx and a pressure atrophy of the ulnar half of each phalangeal epiphysis.

On February 2, 1949, the anterolateral ossicle was removed from the right thumb. The postoperative course was uneventful.

When seen the following year at the Clinic, the motion of the right thumb was found to be quite normal, although a slight degree of abnormal lateral mobility still persisted.

The roentgenograms (Fig. 4-B) revealed that the epiphysis of the distal phalanx on the right side had resumed growth and was in fact overgrown, due to release of pressure from the ossicle. The epiphysis of the distal phalanx on the left side showed greater retardation of growth at the point where the ossicle still pressed against it.

The experience gained in these few cases served to emphasize some points in the management of such conditions. The curvature of the thumb in these four cases is due partly to the unequal growth of the ossicle and partly to interference with the growth of that portion of the epiphysis against which it presses. Since the effect of growth of the

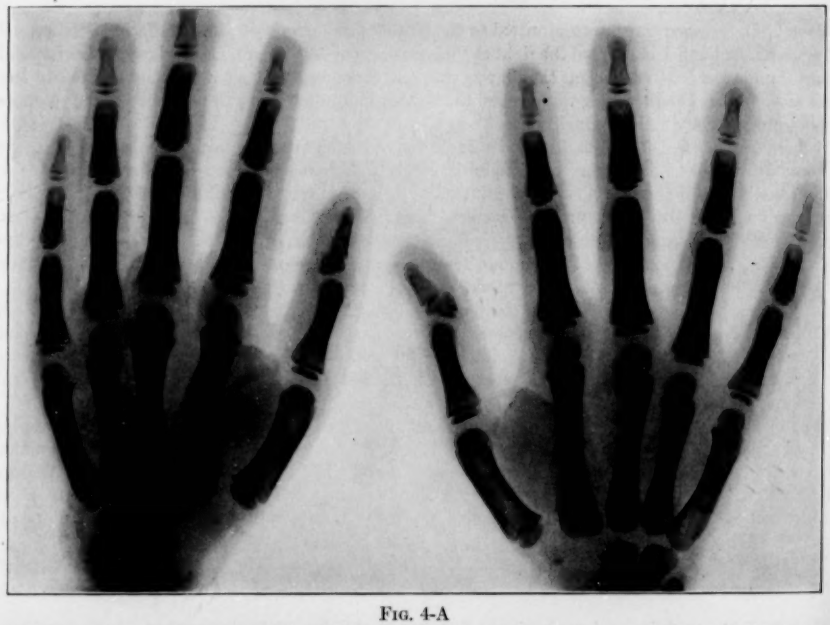

FIG. 4-A

Case 4. A. J. Roentgenograms of both hands before operation. Note wedge-shaped ossicles with bases directed toward the ulna. The phalangeal epiphyses are similarly shaped where pressure of the ossicle has retarded normal growth.

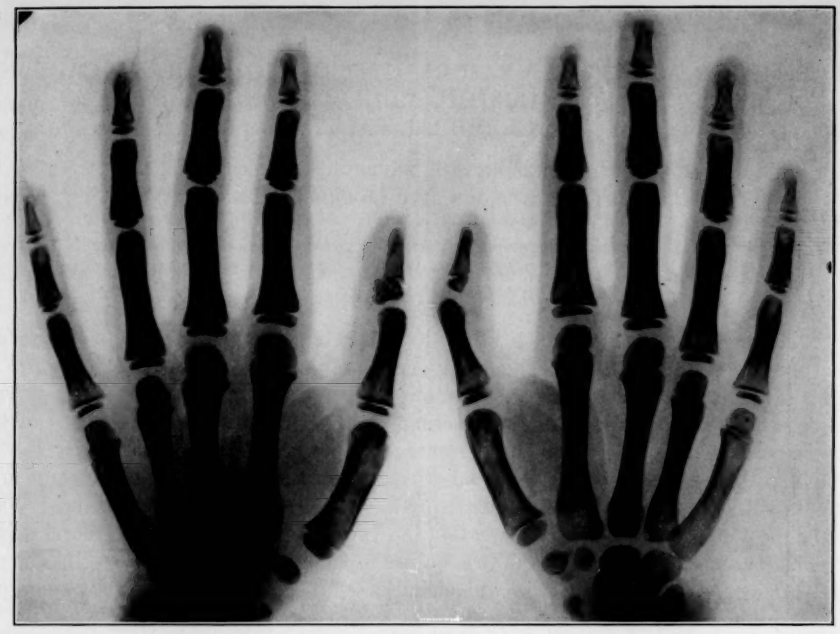

FIG. 4-B

Roentgenograms made one year after the operation. On the right side, the ossicle has been removed. Though still deformed, the phalangeal epiphysis on the right side has resumed growth while that on the left is still retarded.

ossicle itself is to exert pressure upon the corresponding portion of the phalangeal epiphysis, no effort at forcible correction by splint or brace should be attempted. Such force merely tends to more pronounced retardation in the growth of the epiphysis of the distal phalanx.

If the diagnosis is established in infancy or in childhood, the ossicle should be removed surgically. Only in this way can the deformity be overcome. Since the ossicle does not normally serve for the attachment of any muscle or ligament, its ablation does not in any manner alter the function of the thumb. The sooner it is removed, the less is the danger of capsular laxity or epiphyseal damage. In the child, the operation is simple and any defect can be quickly overcome by resumption of normal epiphyseal growth. In the adult, surgery is contra-indicated.

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THE MOTOR AGE TEST: MEASUREMENT OF MOTOR HANDICAPS IN CHILDREN WITH NEUROMUSCULAR DISORDERS SUCH AS CEREBRAL PALSY

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A considerable number of institutions have had large scale experience with cerebral palsy for one or more decades. This experience is reflected in the medical literature. A review of the literature reveals a wealth of impressions and recommendations, but a paucity of precise facts and figures. The lack of factual information makes it impossible to answer such important questions as: What percentage of patients with cerebral palsy can be brought to physical and economic independence through therapy? What percentage of patients with cerebral palsy will become productive citizens without assistance? What are the most efficacious methods of treating the various manifestations of cerebral palsy?

The reason for this state of affairs is quite simple: We are unable to describe the patient with cerebral palsy in any way which lends itself to a statistical analysis; paragraphs of description cannot yield the statistics which are required.

In an attempt at a partial solution of this problem, we determined to devise a test of motor function or ability which would yield a score comparable to the intelligence quotient.* Such a test would enable us, within the limits of the test itself, to objectively grade a child's motor age, to record his progress under various forms of therapy, and to compare the progress of different children with one another, regardless of differences in age or severity of motor handicap.

Because a normal six-year-old child has all the motor abilities necessary for physical independence and for future economic independence, our test has been designed to cover the span of neuromuscular maturation from birth to the age of six years. Any child who possesses all the motor abilities of a normal six-year-old child would not be a candidate for therapy.

In developing the various sections of the test, we drew freely upon Gesell's studies on the normal development of children. In each instance, the test situation has been defined as rigidly as possible in order to make test scores reproducible and to eliminate the influence of bias on the part of the examiner. Many of the more complex skills of the upper extremities, such as feeding one's self, defy objective evaluation. Therefore, artificial situations and mechanical devices which require essential skills for the proper performance of the test have been designed. Further, the artificial situations have been set up in such a manner that clear-cut answers of success or failure can be obtained. Each test item has been designed in such a way as to remove the variable of intelligence from performance, in so far as possible; and each test item has been standardized by trials on normal children.

Because the functions of the upper extremities are more important to a person's physical and economic independence than are those of the lower extremities, and because many patients have significant involvement only of the lower extremities, the motor-age test is divided into two parts. The first part evaluates the motor function of the upper ex-

* The decision to devise our own test of motor function was not made without consideration of previous efforts. The use of *The Physical Demands of Daily Life*[3] was rejected because its component items do not lend themselves to objective analysis. The single set of standards was designed for adults and is not applicable to children of various ages. It has been found that the Oseretsky tests[2] cannot, for technical reasons, be administered to many of the patients with the severe motor handicaps so frequently associated with cerebral palsy.

tremities, and the second part evaluates the motor function of the trunk and lower extremities.

Each test item has been assigned a value, the value being determined by the number of items used in the section at a particular age level and the number of months between that age level and the next lower age level tested. (For example, two test items are used in examining lower-extremity function at the age of thirty-six months; the next lower level tested is thirty months, the difference between which is six months; therefore, each of the two test items used at the level thirty-six months has been assigned a value of three months.) When the motor-age test has been completed, the values of all the test items successfully accomplished are added; the total score is the motor age in months. By dividing the patient's chronological age into the motor age of (1) the upper extremities and (2) the trunk and lower extremities, indices of motor disability or handicap are derived. These indices have been designated the Upper Motor Quotient (UMQ) and the Lower Motor Quotient (LMQ), respectively. Progress, in terms of months of motor age gained, may be correlated with such variables as the type or duration of therapy, diagnosis, and intelligence of the patient.

We have used the motor-age test routinely on all patients at The Edith Hartwell Clinic for the past eighteen months. We have found no sign of practice effect, and test scores obtained by one observer have been independently reproduced by other observers on the same patients. Once physical therapists have become familiar with the techniques of the test, the average patient can be tested in from twenty to forty minutes, depending upon the degree of handicap. The employment of the motor-age test during this brief period has already enabled us to draw certain conclusions which have placed our prognoses on a more sound basis.

TESTING DIRECTIONS

In administering the examination, it is rarely necessary to test the patient on all the items. If for example, in the upper-extremity division (Fig. 1), the patient is able to perform all items at twenty-one and twenty-four months, it may be assumed that he can perform all items below twenty-one months. Similarly, if he fails all items at thirty-six and forty-eight months, it may be assumed that he will fail all items above forty-eight months.

In general, the patient should be allowed to try each test *three times before a failure is scored*, since the examination is designed to measure maximum ability rather than average performance. Furthermore, if the patient becomes bored or tired during the testing and is obviously not functioning well, it is desirable to finish the examination at another time. When practical, the examination should not be administered until the examiner has established some rapport with the patient, especially if the patient is young or is in a new environment.

As previously stated, the examination is divided into two divisions: the upper-extremities division (Fig. 1), and the lower-extremities and trunk division (Fig. 2). Therefore, when the upper extremities are examined, the patient should be wearing any of the braces which he normally wears to stabilize his legs or his trunk or both. If the patient wears braces or other supportive apparatus, such as thumb stalls or plaster splints, on the upper extremities, he should be examined with and without such apparatus, the scores being entered in the *Brace Score* and *No Brace Score* columns, respectively. Similarly, the lower extremities and trunk should be examined with and without the patient's usual bracing. If time does not permit testing both with and without braces, the examination should be made without braces. All braces and apparatus worn during the testing should be indicated in the appropriate spaces on the examination form.

As the patient is examined, successes on each test item should be recorded on the examination form by encircling the score value for the particular test item; failures should be recorded by blocking out the score value of the test item. When the examination is

THE EDITH HARTWELL CLINIC

MOTOR AGE EXAMINATION

NAME: J. B.

DATE: 4 (m) - 5 (d) - 50 (y)

BIRTH DATE: 5 (m) - 22 (d) - 43 (y)

DIRECTIONS: Encircle score of all test items performed satisfactorily; cross out score of items failed. Add encircled scores; total equals motor age in months. All patients to be examined without braces (except upper extremities to be examined with trunk-supporting braces); examination with braces optional. Describe any braces worn at time of exam., e.g. Upper extremities examined while wearing double long-leg braces with pelvic band for trunk support.

UPPER EXTREMITY. Trunk braces: ( ) Full control; ( ) long leg - pelvic band; ( ) pillow splint; ( ) shoulder jacket; ( ) other NONE

		No Brace Score	Brace Score
4mos	Holds rattle	(4)	4
7mos	Grasps 1" cube,	(4)	1
	Thumb participating,	(4)	1
	Transfer to other hand	(4)	1
10mos	Pick up ½" bead precisely, thumb and 1 finger	(4)	3
12mos	½" bead in 2" bottle	(4)	1
	Tower of two 1½" cubes	(4)	1
18mos	Tower of 3	(4)	6
21mos	Tower of 5	(4)	3
24mos	Tower of 6	(4)	1
	Turn pages singly (4 of 6)	(4)	1
	String ½" bead with needle	(4)	1
30mos	Tower of 8	(4)	3
	Use regular crayon with finger grip	(3)	3
36mos	Tower of 9	(3)	3
	10 (½") pellets in 2" bottle in 30 sec.	(3)	3
48mos	10 pellets in 25 sec.	(3)	3
	Electric circle	(3)	3
	3-button circuit 10 sec. best hand 9	(1.5)	1.5
	worst hand 8	(1.5)	1.5
	45 1/8 by 2" pegs into board from dish 180 sec.	~~1~~	3
60mos	Electric square	~~6~~	6
	10 pellets in 20 sec.	~~6~~	6
	SUBTOTALS	~~45~~	

		No Brace Score	Brace Score
	SUBTOTALS		
66mos	2-meter spool winding 20 sec.	~~6~~	.6
	45 pegs in 140 sec.	~~7~~	.7
	5 pegs in board with forceps in 60 sec.	~~7~~	.7
	3 button circuit 10 sec.. best hand 10	~~7~~	.7
	worst hand 9	~~7~~	.7
	Horizontal 2-pairs-button circuit 10 sec. 6	~~7~~	.7
	Vertical 2-pairs-button circuit 10 sec. 6	~~7~~	.7
	Screw knob best hand 55 sec.	~~6~~	.6
	worst hand 60 sec.	~~6~~	.6
72mos	Electric star	.6	.6
	2-meter spool 15 sec.	.6	.6
	5 pegs in board with forceps 35 sec.	.6	.6
	45 pegs in 130 sec.	.6	.6
	3-button circuit 10 sec. best hand 11	.6	.6
	worst hand 10	.6	.6
	Horizontal 2-pairs-button circuit 10 sec. 8	.6	.6
	Vertical 2-pairs-button circuit 10 sec. 7	.6	.6
	Screw knob best hand 50 sec.	.6	.6
	worst hand 55 sec.	.6	.6
	TOTALS	45	

EXAMINER: C. O.

FIG. 1

Score form used for the upper-extremity division of the motor-age test. The scores of patient J.B., a boy, seventy-five months old, with a diagnosis of spastic paraplegia, are recorded on the form. The values of the successfully completed items (which are encircled) total forty-five months. Dividing the motor age (forty-five months) by the chronological age (seventy-five months), an Upper Motor Quotient (UMQ) of sixty is obtained. Despite the absence of grossly visible abnormalities of neuromuscular function in the upper extremities of this patient, his performance is decidedly below normal.

completed all encircled (success) values are added up, and the sum is equal to the upper-extremity or lower-extremity motor age, as the case may be.

SPECIFICATIONS AND DIRECTIONS FOR INDIVIDUAL TEST ITEMS

A. The Upper-Extremity Test (Fig. 1)

Motor age, 4 months.

The patient holds rattle when placed in his hand. Score success if completed with one or both hands.

Motor age, 7 months.

Item 1: The patient grasps a one-inch cube with one hand in any fashion.

Item 2: Score success if the thumb is used in Item 1.

Item 3: Score success if the patient is able to transfer the cube used in Item 1 from one hand to the other.

Motor age, 10 months.

The patient picks up a quarter-inch bead (with flat ends) with the thumb and an opposing finger.

Motor age, 12 months.

Item 1: Score success if the patient is able to pick up a quarter-inch bead (Fig. 3) in any fashion and drop it into a glass jar with an opening two inches in diameter.

Item 2: Score success if the patient is able to place one one-and-one-half inch cube on top of another.

LOWER EXTREMITY: Braces: ( ) Full control; ( ) Long-leg pelvic band;
( ) Bilateral short calipers; ( ) Single (R) (L) short caliper;
J.B. (✓) Pillow splint; ( ) Other _____
4-5-50 ( ) None

If failure of test situation due to arm abnormality indicate: _____

	No Brace Score	Brace Score
4mos Sits, back support, tailor or long, on mat. Head balance almost mastered.	6	6
7mos Sits 1 min. floor, no support, tailor or long.	6	6
10mos Rolls, both ways, complete revolutions.	6	6
Stands holding on to furniture.	6	6
Creeps any fashion, prone or hands-and-knees position.	6	6
12mos Creeps reciprocally, hands-and-knees or all fours.	6	6
Pulls up on furniture to standing.	6	6
15mos Walks with stop-start ability (4 of 6 tries).	6	6
18mos Runs stiffly.	3	3
Up and down standard stairs with rail, any fashion.	3	3
Seats self in suitably-sized chair with arms, away from wall.	3	3
21mos Walks downstairs, holding tech. by 1 hand.	3	3
Walks upstairs, holding rail (1 or 2 hands).	3	3
24mos Runs 50' without falling.	3	3
Walks downstairs, holding rail (1 or 2 hands).	3	3
30mos Jumps, both feet in place.	3	3
36mos Stairs, up and down, alternating feet, no rail or hand	3	3
Jumps from bottom step landing on both feet simultaneously without falling.	3	3
42mos Stands on one foot, 2 sec. (Score if successful on either foot).	6	6
48mos Running broadjump, 12"	3	3
Standing broadjump, 6"	3	3
54mos Hop forward on one foot. (Score if successful on either foot).	6	6
60mos Skip with alternate feet.	6	6
Stand on one foot 8 sec. (Score if successful on either foot).	6	6
Walk 10' line 1" wide, no faults.	6	6
72mos Jump from 12", landing only on toes.	6	6
Stand on alternate feet, eyes closed.	6	6
TOTALS:	21.5	18.5

EXAMINER: M. McG.

FIG. 2

Score form used for the lower-extremity division of the motor-age test. Again the scores of patient J.B. are recorded. When the child was wearing a Frejka pillow splint, because of subluxated hips, the lower-extremities motor age was eighteen and one-half months; when he was not wearing the splint the lower-extremities motor age was twenty-one and one-half months. These motor ages divided by the chronological age (seventy-five months) yield Lower Motor Quotients (LMQ) of twenty-five months and twenty-nine months respectively.

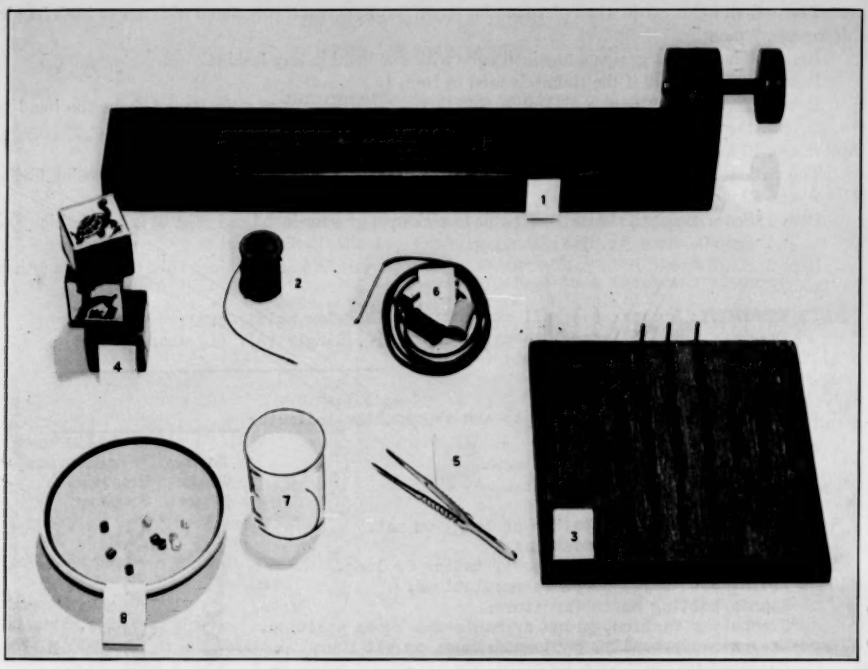

FIG. 3

Apparatus used in the upper-extremity division of the motor-age test. *1:* The supination-pronation screw knob. *2:* Spool with cord. *3:* Pegboard with metal pegs. *4:* Cubes. *5:* Forceps. *6:* String with shoe-lace tip and large beads. *7:* Glass jar. *8:* Saucer and beads.

Motor age, 18 months.

Score success if the patient builds a tower with three one-and-one-half inch cubes (Fig. 3).

Motor age, 21 months.

Score success if the patient builds a tower with five cubes.

Motor age, 24 months.

Item 1: Score success if the patient builds a tower with six cubes.

Item 2: Score success if the patient turns, one at a time, four out of six pages of a child's book (with pages of thick, rough paper).

Item 3: The patient must string a bead one inch long, with a hole one-half of an inch in diameter, on a string equipped with a long shoe-lace tip, measuring two inches by one-eighth of an inch.

Motor age, 30 months.

Item 1: Score success if the patient builds a tower with eight cubes.

Item 2: Score success if the patient is able to hold a regular-size crayon with thumb-and-a-finger grip (adult grip); scribbling constitutes use of the crayon.

Motor age, 36 months.

Item 1: Score success if the patient builds a tower of nine cubes.

Item 2: Ten beads are placed in a deep saucer on the better-hand side of a glass jar with an opening two inches in diameter. Score success if patient is able to pick up ten beads one by one from the saucer and drop them into the glass bottle in thirty seconds.

Motor age, 48 months.

Item 1: Score success if ten beads are picked up one by one and are dropped into the glass jar in twenty-five seconds.

Item 2: The electric circle consists of a circular aluminum track mounted flush with the top of a wooden base (Fig. 4). The diameter of the outer edge of the track is six inches; the diameter of the inner edge is four inches, the track is one inch wide. The aluminum track is connected to one pole of a series-connected pair of No. 6 dry-cell batteries. The remaining battery pole is connected by an insulated flexible wire to one contact of an ophthalmoscope light bulb. The bulb is mounted inside the case of a mechanical pencil, made of transparent

plastic, near the point. The other contact of the bulb is connected to the metal tip of the pencil, so that when the pencil tip is touched to the circular track, the circuit is completed and the bulb is lighted. Success is scored if the patient is able to trace the circle with the pencil without breaking the circuit, keeping the light on.

Item 3: The three-button circuit consists of three push buttons mounted on a wooden base, each button so placed that its center is six inches from the centers of the other two buttons (Fig. 5). The button must be of the microswitch type which requires a minimum of pressure and which requires thumb or finger-tip pressure for operation but which will not respond to palm or fist pressure. The buttons are connected in parallel so that pressure on a single button will complete a circuit consisting of the button, a 7½-watt, 15-volt lamp bulb, and a transformer suitable for converting the available power supply to 15 volts, the three items being connected in series. Pressure on a single button will cause the bulb to light. The patient is instructed in the operation of the apparatus and is then timed to see how many times he can light the bulb by pressing alternate buttons in ten seconds. For motor age, 48 months, score success if the patient lights the bulb nine or more times with the better hand.

Item 4: Score success if patient lights the bulb eight or more times in ten seconds by pressing alternate buttons of the three-button circuit with the worse hand.

Item 5: Forty-five metal pegs, one-eighth of an inch by two inches, are placed in a deep saucer on the better-hand side of a wooden pegboard (Fig. 3). The board contains forty-five holes, three-fourths of an inch apart, and they are arranged in a cross six inches high and six inches wide; each arm and the center square contains nine holes apiece. The patient is timed as he transfers the pegs, one at a time, to the board; any pegs dropped are replaced in the saucer by the examiner. Success is scored if the patient transfers the forty-five pegs from the saucer to the board in 180 seconds or less.

Motor age, 60 months.

Item 1: The electric square is constructed in much the same manner as the electric circle. The outside dimensions of the track are five inches by five inches, and the track is one-half inch wide (Fig. 4). Success is scored if the patient is able to trace the square without error.

Item 2: Success is scored if the patient is able to transfer ten beads from the saucer to the glass jar in twenty seconds.

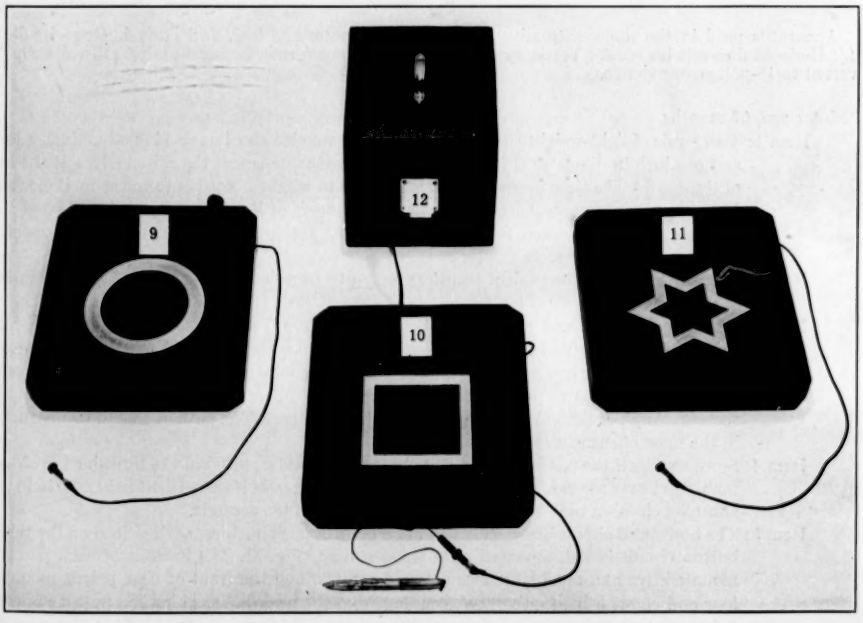

FIG. 4

Apparatus used in the upper-extremity division of the motor-age test. *9:* Electric circle. *10:* Electric square and pencil-mounted light bulb. *11:* Electric star. *12:* Battery box containing series-connected No. 6 dry-cell batteries used for power source for electric circle, square, and star.

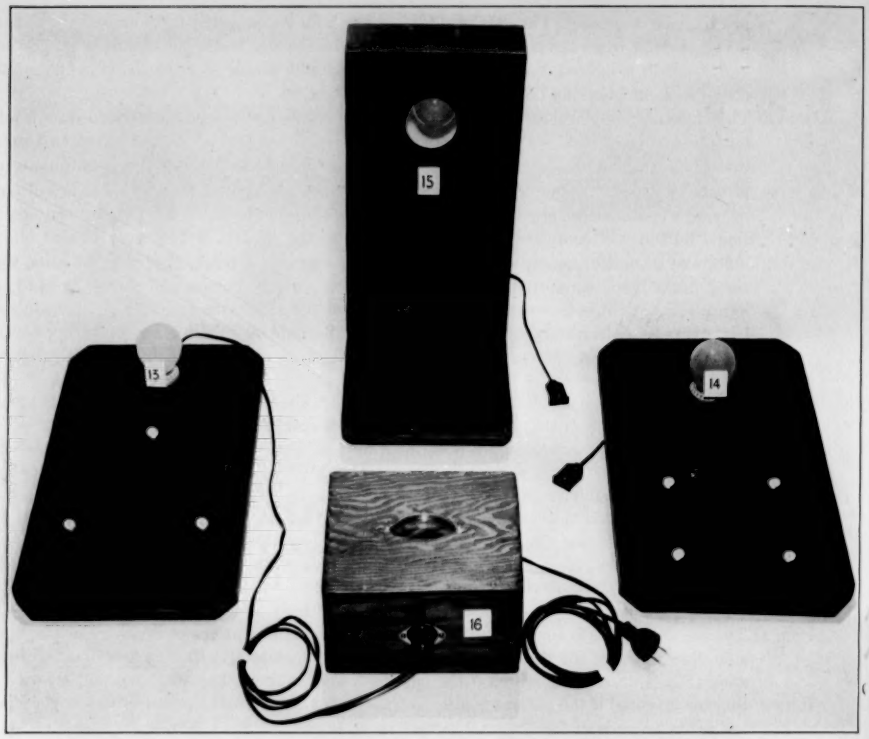

FIG. 5

Apparatus used in the upper-extremity division of the motor-age test. *13:* Three-button circuit. *14:* Horizontal circuit board. *15:* Vertical circuit board. *16:* Transformer box containing 115 volts converted to 15-volt power source.

Motor age, 66 months.

Item 1: Two yards of light-weight cord are attached to a wooden spool one and one-half inches long and one inch in diameter (Fig. 3). (These measurements ignore the raised edges at the end of the spool.) The time necessary for the patient to wind the cord onto the spool is clocked. If any turns are wrapped around the patient's fingers or hand, the time is invalidated and the item must be repeated. Success is scored if the patient winds the cord onto the spool in twenty seconds or less.

Item 2: Success is scored if the patient transfers forty-five pegs from the saucer to the board in 140 seconds.

Item 3: The saucer, board, and five of the pegs used in Item 2 and a pair of toothless, six-inch surgical forceps are used (Fig. 3). Successes are scored according to the length of time necessary to transfer the five pegs from the saucer into the holes of the pegboard with the forceps. Score success if the five pegs are transferred from the saucer and placed in the board in sixty seconds. Any pegs dropped are replaced by the examiner. (The patient should be instructed in the most efficient way to hold the forceps.)

Item 4: Score success if the patient lights the bulb (by alternate circuits) of the three-button circuit ten times in ten seconds with the better hand. Score success if the patient lights the bulb (by alternate circuits) nine times with the worse hand, in ten seconds.

Item 5: The horizontal circuit board consists of two pairs of push buttons, as described on the three-button circuit board, mounted on a wooden base (Fig. 5). The buttons of each pair are mounted five and one-half inches between centers, and the front or near pair is mounted four and one-half inches (between centers) from the back or far pair. The buttons of each pair are connected to their pair-mates in series, so that when both members of a pair are pressed, a 7½-watt, 15-volt bulb (powered by the transformer described earlier) is lighted. The patient is instructed to light the bulb by pressing alternate pairs of buttons. Successes are scored according to the number of times the bulb is lighted (by alternate circuits) in ten

seconds. Score success if the patient lights the bulb (by alternate circuits) six or more times in ten seconds.

Item 6: The vertical circuit board is electrically similar to the horizontal board. However, the push buttons are mounted back-to-back on the sides of a vertical wooden base. The upper pair is six and one-half inches (between centers) above the lower pair, and the buttons of each pair are ten and one-half inches between centers. A bulb is lighted by pressing both buttons of either pair simultaneously. The patient lights the bulb by pressing the buttons of the two pairs alternately. Successes are scored according to the number of times the bulb is lighted by alternate circuits in ten seconds. Score success if the bulb is lighted six times (by alternate circuits) in ten seconds.

Item 7: The supination-pronation screw knob consists of a bolt fitted with a round wooden handle three-fourths of an inch thick and two inches in diameter at the head or the non-threaded end (Fig. 3). The bolt is threaded with twenty-one turns. The mating nut is mounted in a vertical upright which can be clamped to a table top for stability. The bolt is barely started in the nut by the examiner. The patient screws the bolt in as far as it will go and then unscrews it until the bolt falls out. Success is scored according to the length of time required for this operation. Success is scored if the patient does the whole operation in fifty-five seconds with his better hand or in sixty seconds with his worse hand.

Motor age, 72 months.

Item 1: The electric star (Fig. 4) is constructed in a manner similar to the electric circle previously described. The star has six points, the points lying on a circle six inches in diameter. The track of the star is five-eights of an inch wide. Success is scored if the patient is able to trace the star without error.

Item 2: Score success if patient winds cord onto wooden spool in fifteen seconds or less.

Item 3: Score success if the patient transfers five pegs, one at a time, from the saucer with a forceps and places them in the pegboard in thirty-five seconds.

Item 4: Score success if the patient transfers forty-five pegs, one at a time, from the saucer to the board in 130 seconds.

Item 5: Score success if the patient lights (by alternate circuits) the bulb connected with the three-button circuit eleven times with the better hand and ten times with the worse hand, in ten seconds.

Item 6: Score success if the patient lights (by alternate circuits) the bulb of the vertical circuit board seven times in ten seconds.

Item 7: Score success if the patient completes the supination-pronation screw-knob operation in fifty seconds with his better hand and in fifty-five seconds with his worse hand.

B. The Lower-Extremities and Trunk Test (Fig. 2)

Motor age, 4 months.

Item 1: Score success if the patient is able to sit on a mat, leaning against the wall with his legs partially extended and abducted, or with his legs crossed (tailor fashion).

Item 2: Score success if the child, while held upright in the sitting position, is able to raise his head so that the chin is not resting on his chest, at least momentarily.

Motor age, 7 months.

Score success if the child is able to sit alone (without back rest) one minute on the floor, supporting himself on his hands if necessary. Disregard head posture. Legs may be in any position. Trunk must not flex forward more than 45 degrees from the perpendicular.

Motor age, 10 months.

Item 1: Score success if the child is able to roll, making complete revolutions both ways.

Item 2: Score success if the child, when placed in position, is able to grasp a supporting object and bear own weight for thirty seconds. (If patient's hand function is so poor that he cannot grasp, this item should not be scored against him.)

Item 3: Score success if the child is able to drag his body along in any fashion a distance of six feet in one minute, using arms or legs or both, not necessarily in a coordinated movement. (Progression in sitting position using arms is scored as success.)

Motor age, 12 months.

Item 1: Score success if the child is able to creep six feet in fifteen seconds on all fours in reciprocal motion with trunk off floor.

Item 2: Score success if the child is able to pull himself up in a play pen (or on some other similar support from the floor) using one or both hands, and maintain his position.

Motor age, 15 months.

Score success if the child is able to walk six steps, stop, then start again without falling.

Motor age, 18 months.

Item 1: Score success if the child is able to hasten walking step into a stiff running gait and run fifty feet without falling.

Item 2: Score success if the child is able to climb standard stairs without rubber treads in any fashion unassisted by examiner. (Any method selected by child is acceptable, such as crawling, sitting, walking, with or without the aid of the hand on rail or wall.)

Item 3: Score success if the child is able to seat himself in an arm chair of suitable size (proportional to size of patient), the chair being unsupported by either the examiner or wall.

Motor age, 21 months.

Item 1: Score success if the child is able to walk down six standard-riser steps, holding one hand of examiner. (Examiner is to assist only in maintaining balance and is not to give true support.)

Item 2: Score success if the child is able to walk up six standard stairs using one or both hands on rail or wall, unassisted by examiner.

Motor age, 24 months.

Item 1: Score success if the child is able to run fifty feet without falling and with agility, that is, normal running.

Item 2: Score success if the child is able to walk down stairs using one or both hands on rail or wall, without assistance from examiner. (Not necessarily reciprocating.)

Motor age, 30 months.

Score success if the child is able to jump in place, getting both feet off the floor together.

Motor age, 36 months.

Item 1: Score success if the child is able to walk up and down six standard stairs without assistance of examiner, rail, or wall, using alternate feet, and placing only one foot on each step.

Item 2: Score success if the child is able to jump down from the bottom step (average height riser) to floor, landing on both feet simultaneously, and maintaining balance without holding.

Motor age, 42 months.

Score success if the child is able to maintain standing balance (without holding) on one foot for two seconds.

Motor age, 48 months.

Item 1: Score success if the child is able to run six feet and (without stopping at jump line) make a broad jump of twelve inches, landing with both feet together.

Item 2: Score success if the child is able to stand still, both feet together, and jump six inches, two feet together, landing with feet together, and maintain balance (without holding).

Motor age, 54 months.

Score success if the child is able to hop four steps forward on one foot. (Score success if successful on either foot; patient is not required to perform successfully first on one foot and then on the other.)

Motor age, 60 months.

Item 1: Score success if the child is able to skip a distance of ten feet using alternating feet.

Item 2: Score success if the child is able to hold his balance on a single foot for eight seconds.

Item 3: Score success if the child is able to walk ten feet on a line one inch wide. It is not necessary to tread squarely on the line, but some part of the foot must touch it at each step.

Motor age, 72 months.

Item 1: Score success if the child is able to jump from a platform twelve inches high, landing only on the toes of both feet simultaneously (and then coming down onto heels), maintaining balance without holding.

Item 2: Score success if the child is able to balance himself momentarily on one foot and then change to the opposite foot, keeping the eyes closed throughout. Marking time in place is not enough to score success; the patient should be on a single foot long enough for the examiner to see that he has attained balance, and then he must shift to the other foot and attain balance; the eyes must be closed throughout.

DISCUSSION

In terms of accuracy and reliability, the motor-age test obviously cannot be compared with the various types of aptitude tests which have been worked out on a large, expensive scale by cooperative testing organizations with a background of considerable experience. On individual test items, for example, it may be argued that the assigned motor age is incorrect. Such errors, if present, are consistent; and therefore they do not affect the calculated rate of progress made by patients under therapy. As stated, no practice effect has been noted, and test results are reproducible. The effects of variations in intelligence and

emotional status are unknown, although we have attempted to eliminate the factor of intelligence from the performance of the test, in so far as possible.

Despite these limitations, the authors feel that the motor-age test is a useful, though an imperfect tool. It has stimulated objectivity on the part of therapists and physicians; and has produced numerical data adaptable to statistical analysis, which are far more valuable than qualitative descriptions.

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OPERATION FOR HABITUAL DISLOCATION OF THE ELBOW

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Habitual dislocation of the elbow is a rare disability, in marked contrast to the relatively frequent occurrence of this condition involving the shoulder and patella. A survey of the literature revealed only five reported cases. These represent a rather heterogeneous group, comprising a medial dislocation of both radius and ulna occurring in flexion (Albert); a subluxation of the head of the radius accompanying flexion (Wendel); a divergent dislocation occurring in flexion, the radius going anteriorly and laterally, the ulna posteriorly and medially (Heusner); and finally, two posterior dislocations of both bones, one occurring in extension (Stapelmohr), while in the other (Bloch) the position was not specified.

Since 1943 two cases of true posterior recurrent dislocation of the elbow have come to the author's attention. One of these was operated upon seven years ago and has been followed up to the present time. In view of the rarity of this condition and the success of the relatively simple operative procedure employed, publication of these cases seems justified.

Case 1. A wig-maker, single, twenty-one years old, was admitted to Copenhagen County Hospital, June 15, 1943 (Rec. No. 1636/43), complaining of recurrent posterior dislocation of the left elbow.

Family and past history were non-contributory.

Present Illness: Dislocation of the left elbow occurred first at the age of five or six years when the patient fell into a hole he was "helping" to dig. Since then he had had recurrent posterior dislocations of the left elbow and occasionally of the right elbow as well. These resulted from slight and indifferent trauma, as, for example, in gymnastics when he had to vault over the horse. As a rule, he was able to effect reduction himself, but not infrequently medical assistance was required. After each dislocation there was swelling and tenderness in the elbow for some time, and he would have to carry his arm in a sling. The disability from this was such that he had been unable to pursue the trade of his choice, cabinet-making, and in addition, was incapacitated for his present occupation, assisting his father as a hairdresser and wig-maker. He was constantly uneasy about his left elbow because of repeated dislocations consequent to the slightest movement. Recently he had been called to duty for civilian defense, having been rejected previously for military service because of his elbow. On one occasion, when he was commanded to stand at attention, his left elbow had dislocated. Shortly after this he was admitted to the Hospital.

Physical Examination: The left arm was carried in a sling; the elbow was swollen and tender. There was distinct atrophy of the radial group of muscles, as compared to those on the right side. Although the contour of the joint seemed normal when viewed from the front, the lateral view revealed slight dorsal displacement of the forearm in relation to the upper arm when the elbow was extended or slightly hyperextended. Both elbows in the extended position showed unquestionable lateral-medial laxity. The examination was otherwise negative.

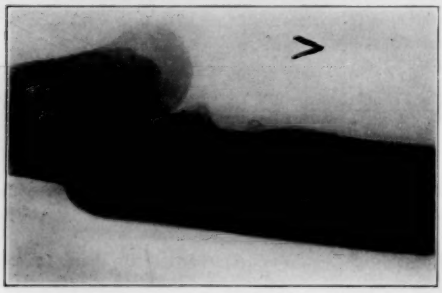

FIG. 1-A

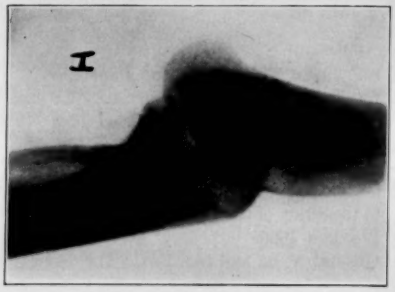

FIG. 1-B

Roentgenograms showed on the left (Fig. 1-A), posterior dislocation, and on the right (Fig. 1-B), posterior subluxation in the position of extension. When flexed, however, both joints appeared normal except for the rather shallow semilunar notch.

Treatment: Since the patient was incapacitated, operative treatment seemed justified. This was performed under ether anaesthesia, utilizing two incisions, one anterior and one posterior, the latter extending not quite to the top of the olecranon process. Through the former, the biceps tendon was identified and followed to its insertion. This tendon was then split longitudinally in a proximal direction to include some of the muscle. The lateral half was divided at its upper end, making a strip of tendon and muscle measuring 12 by 1 by 1 centimeters which was still attached distally to the radial tuberosity. The free end of this was then pulled into the posterior incision through the substance of the brachialis and through a hole drilled in the thin lamina of bone separating the coronoid and olecranon fossae (Fig. 2). Here it was sutured to the tip of the olecranon and the tendon of the triceps with the elbow at 90 degrees of flexion. In a similar fashion, a strip from the center of the triceps tendon, measuring 10 by 1 by 1 centimeters, free proximally and left attached distally, was mobilized and pulled through the same hole in the opposite or anterior direction and sutured to the coronoid process or deep fibers of the brachialis with the elbow also flexed to 90 degrees. The two remaining portions of the triceps tendon were then approximated in the mid-line with sutures and both wounds were closed.

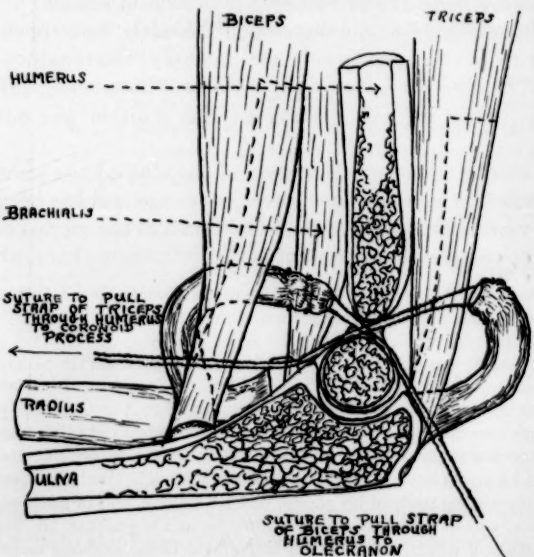

FIG. 2

Postoperatively the elbow was immobilized in flexion of 90 degrees. This position was adopted since it was desired to have both straps tighten anteriorly in extension, thus checking both the radius (with the biceps strap) and the ulna (with the triceps strap) from slipping backward in extension and thus dislocating posteriorly.

Postoperative Care: The wound was dressed and the sutures were removed on the eighteenth day. A new cast was applied three days later and immobilization in flexion of 90 degrees was continued for three weeks more, a total of six weeks. Gradual mobilization was then started and nine weeks postoperatively the patient had full flexion and extension of 135 degrees, the elbow being entirely stable. After eight months he was back at work with free motion in all planes. In full extension there was some lateral-medial laxity, but he had not had a recurrence.

Follow-up examination in 1950, seven years after operation, revealed that he was still working and had not had a recurrence of the dislocation on the left, the side operated upon. He had, however, had two dislocations on the right side. Operative treatment did not seem indicated on the right side at that time.

CASE 2: A barber, twenty-eight years old, came to the author's attention in 1949. At the age of thirteen or fourteen, during gymnastics at school, he had dislocated his left elbow for the first time, while vaulting the horse. This was reduced by a doctor, and he had no further symptoms until four years later, when, while shovelling, his left elbow again dislocated, this time reducing itself spontaneously. Subsequently he had repeated dislocations resulting from certain movements, such as putting on his coat. He was always able to reduce the dislocation himself, following which there would be some tenderness of the joint lasting for a few days.

Although he was able to work as a barber without discomfort, his elbow dislocated as often as every month, and he was constantly on his guard trying to avoid this. Extension produced a sensation of impending dislocation. He was unable to do even moderately heavy work. He had been rejected for military service because of this disability. There were no symptoms referable to his right side.

The history was otherwise non-contributory, except that his daughter, aged four, had had two dislocations of her elbow, resulting from minor injuries.

Physical Examination: The left elbow showed pronounced medial-lateral laxity, associated with crepitus. Atrophy of the biceps, flexor-pronator, and brachialis muscle groups was apparent on the left. The right elbow was normal.

Roentgenograms (Figs. 3-A and 3-B) showed findings on the left similar to the first case,—namely a tendency to dislocate in extension, a rather shallow semilunar notch, and an old fracture of the lateral epicondyle apparently ununited. The right elbow, on the other hand, was normal.

Operative treatment was advised but declined for financial reasons.

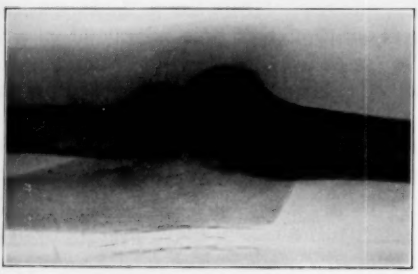

FIG. 3-A

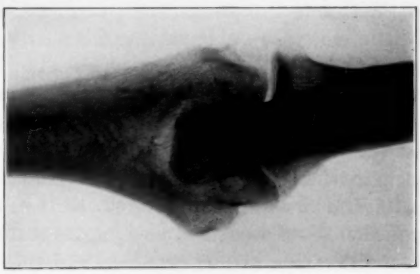

FIG. 3-B

DISCUSSION

Out of this rather heterogeneous group of cases, including those found in the literature and the author's two cases, there emerge three which seem to represent a definite entity,—namely, a posterior dislocation, occurring in extension and produced by an impacting force. The cases comprising this group are Stapelmohr's and two reported here. Bloch's and Heusner's cases, although different types of dislocations, had certain features in common, including a traumatic origin, a shallow trochlear notch, and an old avulsion fracture of the lateral epicondyle.

The pathogenesis of these recurrent posterior dislocations seems to depend upon two things,—an abnormal semilunar notch and laxity of the collateral ligaments, particularly the lateral.

The incisura semilunaris in all instances was noted to comprise less than the normal semicircle and to be decidedly flattened, rendering the joint unstable. The origin of this defective ulnar articular surface may be either congenital or acquired. The two cases reported here lend some support to the idea of a congenital origin, for the first was bilateral, and the second patient had a daughter who had had two elbow dislocations. However, in the bilateral case, the left elbow, the one most frequently dislocated, showed much more flattening, suggesting that this abnormality may have progressed with repeated dislocations.

In this connection, fracture of the coronoid process is frequently mentioned as predisposing to habitual dislocation. However, a thorough search of the literature revealed no such case following this fracture and indeed Urlichs, in 1898, came to the same conclusion.

Ligamentous laxity was noted clinically in the author's two cases. Both showed definite lateral mobility in extension. Furthermore, there was corroborative x-ray evidence both in these cases and in those reported in the literature,—namely, old avulsion fractures of the lateral epicondyle. Case 1 varied slightly in that the first roentgenograms taken showed an osseous shadow in the soft parts, close to the lateral epicondyle, which was not found in subsequent films.

Still another case of the author's, not reported here, emphasizes the importance of fracture of the lateral epicondyle as a contributing factor. This was a man, thirty-two years old, who had dislocated his right elbow twice as the result of falls,—the first time ten years before, when jumping over a tennis net, and the second, five years before, while playing football. A roentgenogram four years after this showed a free bone shadow near the lateral epicondyle.

In short, then, this type of habitual elbow dislocation seems to result from an injury which produces an avulsion fracture of the epicondyle with resulting ligamentous laxity. This may be due in some measure to inadequate initial treatment. Associated with this is a shallow semilunar notch which may be either a predisposing abnormality, of congenital origin, or it may develop as the result of repeated luxations.

With two exceptions, the treatment of this rare condition in the past has consisted of little more than extirpation of loose fragments of the lateral epicondyle and no long-time follow-up has been carried out. In Heusner's case where the ulna dislocated posteriorly and the radius anteriorly, he attempted to gain stability by surgically deepening the incisura semilunaris. Exact details are not recorded, but this apparently resulted in more or less complete ankylosis. Stapelmohr attempted to achieve the same result by an extra-articular procedure enlarging the olecranon and coronoid processes with iliac bone grafts, thus deepening the notch. In this instance follow-up examination one year after operation showed normal motion except for extension, which was limited to 170 degrees. No redislocation had occurred.

The author's method has proved successful in one particularly severe case which has been followed for seven years. It has the merit of being quite simple technically, with little risk of the serious loss of motion which might be anticipated in any procedure attempting to change the joint contours.

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THE THERAPEUTIC VALUE OF REFRIGERATION IN ACUTE TRAUMATIC ARTERIAL DEFICIT

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In acute circulatory impairment of an extremity, it may be assumed that cold will so reduce the local metabolic needs that the extent of tissue damage is diminished. It has been suggested that an extremity might be preserved until the establishment of a collateral circulation, the suspended period allowing for compensatory dilatation of the collateral vessels. In May 1945, Allen made a strong plea for the adoption of therapeutic limb refrigeration in war surgery. At that time, however, adequate trial could not be undertaken. Livingstone also suggested that "refrigeration *without* a tourniquet might be successfully employed in some cases of acute vascular deficit in which survival of the limb is anticipated"; later, A. G. Kanaar, in a comprehensive review of refrigeration in the treatment of trauma, urged its trial in cases of war wounds with major arterial lesions.

Consequent to Israeli-Arab hostilities, fifty-three major limb amputations were performed at this Hospital. A high proportion of the injuries consisted of multiple wounds caused by shell or mine explosions. Of these fifty-three patients, twenty underwent refrigeration of the extremity. Their ages ranged from seventeen to fifty-three years; there were eighteen males and two females. Three deaths occurred,—one due to associated thoracic injuries, one to gas gangrene, and the third to toxaemia.

The method of refrigeration employed was a simple modification of that originally described by Allen. Sterile dressings were placed over the wounds and the limb was encased in thin rubber sheeting; a large rubber sheet was spread out on the bed and on it was placed a trough of cracked ice about 10 centimeters in depth and double the width of the limb. The injured limb was laid in the trough and more ice added until the limb was encased. The rubber sheet was then folded over and tied loosely about the limb. The head of the bed was raised on blocks so that the ice water could drain. This method produces tissue temperatures of 5 to 10 degrees centigrade. Surgical excision, which might have interrupted existing collateral vessels, was avoided. Obviously no tourniquet was used. The period of refrigeration ranged from five to twenty-four days. Refrigeration was used in conjunction with antibiotic therapy, transfusions, and various methods of stimulating dilatation of the collateral channels.

ANALYSIS

The twenty refrigeration cases may be classified as follows:

A. Cold Storage Therapy.....two cases.
Both patients had severe multiple injuries.

CASE J. M. M., a soldier, twenty-seven years old, was injured by shell fragments; he suffered intra-abdominal injuries, necessitating a colostomy and resection of 25 centimeters of small bowel. He had a compound fracture of the right forearm and multiple face injuries. In addition, the right leg was mangled and pulped. A below-the-knee amputation was clearly indicated, but his general condition did not permit this. The leg was refrigerated. After eleven days, the patient's general condition had sufficiently improved to permit elective below-the-knee amputation.

CASE J. H. V., a male civilian, thirty-two years old, injured by an exploding mine, suffered traumatic amputation of the right leg with extensive lacerations up to the buttock, facial injuries, and a penetrating wound in the right lower portion of the chest. The left arm was a mass of pulped bone and soft tissue. The limb was refrigerated. Seven days later, when the patient was in good condition, amputation was performed.

Refrigeration as used in these cases serves the same purpose as that applied to meat,—it prevents decomposition. This method is used to preserve a "dead" limb which cannot be amputated but which could cause a severe toxaemia. It permits delay of the amputation, thus transforming an emergency operation into an elective procedure.

B. Tourniquet Gangrene.....one case.

Case M. G., a seventeen-year-old soldier, suffered a compound fracture of the right forearm. A tourniquet at mid-humerus level had been applied in the field, and in error was left undisturbed for twelve hours. At the time of admission, the arm appeared pale, with blotchy areas of cyanosis, and the viability of the limb seemed doubtful. The limb was refrigerated, and the tourniquet was removed. After nine days of refrigeration non-viability was apparent and an above-the-elbow amputation was performed. Despite refrigeration, an anuria developed which persisted for thirty-six hours; without it, an even more severe toxaemia would probably have developed.

C. Acute Arterial Deficit Due to Injury.....seventeen cases.

In each of these cases there was an irregular laceration or a complete tear in the main artery of the limb. The arterial incidence was as follows:

	No. of Cases
Common femoral	4
Popliteal	10
Axillary	2
Anterior and posterior tibial arteries	1

There were usually other wounds in the damaged limb, both distal and proximal to the arterial injury, which further complicated the clinical picture.

Refrigeration was generally begun within four to eight hours of injury. Experience with these cases leads to the following observations:

General Condition of the Patient

With refrigeration, the patient was almost free of pain and his general condition improved rapidly. Multiple injuries were common; 43.4 per cent. of the cases underwent other major emergency operations, and the predominating injury often was not the limb injury discussed here. Refrigeration allowed priority for these other operations and postponement of the limb amputation until it could be performed as an operation of choice. In war surgery this postponement is of great value.

Infection and Toxaemia

Immediately following refrigeration, the patient's temperature fell to normal and there was no further spread of inflammatory reaction. Refrigeration was markedly effective in arresting toxic absorption and inhibiting local bacterial growth. Toxaemia occurs only if the area is being ineffectually cooled. This is evident particularly in patients suffering from diabetic or senile gangrene, for whom operation must be de ayed.

Effects on Collateral Circulation

In each case the line of demarcation corresponded with that to be expected for an arterial lesion at that particular level. Mock reported a case of acute arterial deficit under refrigeration in which color changes in the skin of the limb evidenced the gradual establishment of a collateral circulation. This he observed in at least five cases and termed it the "preservation of tissue" phenomenon, which permits amputation at a lower level. In this series no color changes or unusual development of collateral circulation were observed.

Restriction of Swelling and Development of Dry Gangrene

Following refrigeration, the skin was a pinkish white in areas where the circulation was adequate, and had a blue cyanotic appearance in areas with inadequate circulation. The demarcation of the two areas, indefinite at first, progressively became better defined. Normally the proximal level of gangrene and the line of demarcation are evident by the fifth day; with refrigeration, the line of demarcation is not definite until the twelfth to sixteenth day.

When refrigeration was applied prior to the development of tissue swelling, no swelling occurred. Langohr and his associates substantiated this finding experimentally by using therapeutic cold on thermal burns in dogs. They observed that lymph flow was retarded and oedema formation was reduced.

Whether a gangrene is moist or dry depends upon the fluid content of the tissues. In arterial interruption, owing to tissue anoxia, the capillaries become permeable and plasma leakage occurs, resulting in oedema of the limb and moist gangrene. Refrigeration inhibits oedema and swelling and prevents the development of a moist gangrene. Instead, a dry gangrene with tissue shrinkage and mummification occurs; a distinct clinical advantage is thereby gained.

Continued Oozing from Wounds

For some days following refrigeration there was a steady blood-stained leakage of fluid from the wounds, though no clinically significant blood loss was involved. It is recognized that the speed of a chemical activity is increased or decreased two or three times for every rise or fall in temperature of 10 degrees centigrade. The prolonged bleeding following refrigeration may therefore best be explained by the reduction in the rate of enzymatic activity and of coagulation.

Oxygenation and Anaerobic Infections

Dissociation of oxyhemoglobin is reduced as the temperature is lowered; below 10 degrees centigrade it does not occur [11]. The bright pink color of the tissues during refrigeration at 10 degrees centigrade is due to the high concentration of oxyhemoglobin in both the arterial and venous vessels. It is clear that cellular metabolism continues under refrigeration. This is manifested by the tissue changes which occur and by the appearance of the line of demarcation. One hundred cubic centimeters of normal blood carries 18.5 cubic centimeters of "combined" oxygen and only 0.3 cubic centimeters in simple solution in the plasma. In refrigeration the only oxygen available for tissue metabolism is the small volume in the plasma. Thus refrigeration in acute arterial deficit reduces the metabolic needs of the part but also markedly reduces the oxygenating capacity of the already restricted blood supply. The depression of metabolism is accompanied by a corresponding depression of oxygenating capacity.

In this series there were four cases of gas gangrene, one of them fatal. This incidence is considered abnormally high. Cayford and Pretty reported twenty-two cases of amputation under refrigeration anaesthesia, in which three deaths from gas gangrene occurred. Both Kirz and Hughes have reported deaths due to gas gangrene following amputation under refrigeration.

It is believed that because of the inability of oxyhemoglobin to dissociate and because of the restricted blood supply in the affected area, an anaerobic soil is created. The gas bacillus does not develop below 10 degrees centigrade, but temperature fluctuations above this level allow its growth. Failure to refrigerate the limb well proximal to the site of arterial injury permits temperature variations, an anaerobic field, and the development of gas gangrene. Contaminated wounds proximal to the level of arterial injury were usual in this series. Refrigeration to inhibit gas gangrene must be effective well above the most proximal wound of the limb.

Withdrawal of Refrigeration

During refrigeration, tissue responses to inflammation are retarded; at its cessation there is an immediate rise in blood flow, and the inflammatory reaction is aggravated. Ceasing refrigeration before the onset of mummification was found to be a dangerous procedure. The limb rapidly deteriorated, became swollen, oedematous, and discolored by ecchymoses, and showed superficial blistering of the skin. A severe toxaemia rapidly developed; this was responsible for one death in this series. The post-refrigeration flare-up

is a very definite clinical entity. Refrigeration must be continued until dry gangrene supervenes, when an elective amputation may be performed or a decision may be made to amputate the limb while it is under refrigeration. Cessation in order to determine viability of the limb is inadvisable.

SUMMARY

1. Limb refrigeration for periods ranging from five to twenty-four days was used in twenty cases of traumatic extremity vascular deficit.

2. The greatest value of limb refrigeration was found in cases of multiple injuries, when the patient's general condition was unsatisfactory. It allowed other emergency operative procedures to be undertaken while the limb was placed in cold storage until an elective and safe amputation could be performed. This form of therapy has a field of application in war surgery.

3. No unusual development of collateral channels or "preservation of tissue" was noticed. The level of the line of demarcation coincided with that normally to be anticipated without refrigeration.

4. Refrigeration prevented the development of moist gangrene and produced a comparatively safe dry gangrene. The whole tempo of change in the affected limb was markedly slowed. The appearance of the line of demarcation was delayed until the twelfth to sixteenth day.

5. Four cases of gas gangrene occurred. At low temperatures, oxyhemoglobin does not dissociate and a relatively anaerobic field is produced. Proximal contamination and temperature fluctuation thus account for this high incidence.

6. Withdrawal of refrigeration before the development of dry gangrene caused a rapid deterioration of the limb and a fulminating toxaemia.

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COCCYGODYNIA AS REFERRED PAIN

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Coccygodynia, a painful condition of the coccyx, is frequently caused by trauma, although it may arise without any known cause. The treatment most commonly employed consists in rest of the injured part to permit healing. If conservative treatment fails, surgical removal of the coccyx is advocated [3, 7, 18, 19, 23, 29].

In a study of low-back pain, Shapiro found that many such cases are associated with pain in the coccyx and that, by eliminating the back pain, the coccygeal pain frequently disappears. Treatment of the painful lesions consisted in injection of procaine to produce a nerve block of the upper three sacral nerves.

Thorek believes that coccygodynia is generally a neurotic symptom and that psychotherapy is often indicated. Finder states that coccygodynia has long been considered a syndrome in which the functional element plays a major role. He advises the procedure of manipulation of the coccyx, instructs the patient in the technique of self-manipulation, and reports beneficial results in all types of cases, whether they have a functional or an organic basis. According to Watson-Jones, "The functional and psychological aspect of coccydinia has been exaggerated. The victims of this disorder exhibit few or none of the usual manifestations of functional disturbances, and, if their complaint of pain is accepted and treated as it should be, their recovery is usually quite complete." Böhler declared that he has never seen such cases following an injury.

Thiele, Wilensky, and Wilkinson interpreted coccygodynia as a clinical entity caused by spasm or by inflammation of the pelvic-floor muscles,—the piriformis, the levator ani, and the coccygeus. Manual massage of these muscles has yielded satisfactory results in a large series of cases.

From observations on five patients during the past few years, there is reason to believe that coccygodynia is referred pain, arising from structures elsewhere in the lower part of the back. The site of the primary pain is determined by eliciting tenderness on palpation; this was established, in all instances, in the mid-sacral region near the mid-line. In that location, it is often possible to palpate nodules or masses of tissue which are distinctively sensitive to pressure. It was suspected, and later confirmed, that the structures from which the pain arises consist of fat tissue situated in the subfascial spaces.

Abnormalities of fat tissue as factors in certain painful syndromes have been investigated and reported by Copeman, and Copeman and Ackerman. After determining and charting a "pain pattern" in the lower part of the back, they found, on anatomical dissections, deposits of fat tissue which had undergone pathological changes, giving rise to pain. Several forms of abnormality in fat tissue are described [4, 5],—herniation through the deep fascia, occurring most commonly along the lateral margin of the sacrospinalis from the lower costal border to the iliac crest, and oedema resulting in tension of the fat lobules, found most frequently in the sacral region and below the rim of the iliac crest. It was established, by injections of procaine and by surgical removal of the fat tissue, that painful syndromes may result from abnormalities of this nature. Additional reports by Herz, Moes, Hucherson and Gandy, Orr, Mathers and Butt, Hittner, and Dittrich have confirmed the influence of pathological alterations in fat tissue as an important factor in painful conditions affecting the lower part of the back.

Referred pain and associated phenomena related to deep somatic pain have been extensively investigated by Lewis and Kellgren, Kellgren [15, 16, 17], Inman and Saunders, Sinclair, Weddell, and Feindel, Wolff and Wolf, Travell, and others. From these studies, it has been established that referred pain has a spinal segmental pattern in its distribution

and that the afferent innervation of deep somatic structures differs radically from the pattern of dermatomic supply. It is also considered likely that referred pain is due to misinterpretation by the central nervous system, whereas referred tenderness is probably caused by chemical activity of metabolites deposited in the tissues. The exact nature and the channels of referred phenomena are not clear; some investigators contend that the entire process of reference takes place in the periphery, whereas others insist that participation of the central nervous system is necessary.

CASE REPORTS

CASE 1. A.L.A., a white male, aged twenty-four years, was seen in August 1949. He stated that four weeks previously, while pulling a hand truck, he had been forcibly jerked downward, with his back bent forward. He noted pain immediately in the lower part of his back. This became so intense that he had to discontinue work for several days and to perform light work thereafter. The pain was aggravated by lifting, stooping, and sitting. It was distributed over a large area of the back, including the lower end of the spine where it was especially severe when he was sitting with his legs crossed.

Examination showed no deformity and the motions of the spine were normal in range, causing pain in the lumbar and sacral regions. Marked tenderness was elicited over the lateral margin of the sacrospinalis at the level of the second and third lumbar vertebrae, on both sides. Less marked tenderness was noted over the coccyx and on both sides of the mid-line at the level of the third sacral segment.

As a diagnostic measure, the tender sites in the iliolumbar region were injected subfascially with five cubic centimeters of 2 per cent. procaine. This procedure eliminated the pain and the tenderness in those areas. The manifestations in the sacral and coccygeal regions were unchanged.

Several days later the pain and tenderness in the iliolumbar region had disappeared. Tenderness was still present in the coccyx and on both sides in the sacral region. After an injection of three cubic centimeters of procaine subfascially into the sensitive areas of the sacrum, the tenderness was eliminated. Four days later, the pain had diminished, and there was no significant tenderness anywhere in his back.

The man was seen again about two months later and stated that his pain had disappeared entirely, shortly after the last injection. There has been no recurrence of the symptoms during a period of ten months' observation.

CASE 2. Mrs. M. L. L., white, aged thirty-seven, was examined in December 1948. Four months previously, she had fallen and struck the lower part of her back against a crate. Several hours later she noted pain in her back, which gradually became more intense. The pain was most pronounced at the lower end of her spine, and she stated that for a period of three months she had been unable to sit. She complained of a constant ache with a sharp pain on activity.

The examination showed marked tenderness of the coccyx and the lower portion of the sacrum; examination also revealed two small areas of tenderness in the sacral region on the right side. Each of the latter—one at the approximate level of the first sacral segment, the other at the level of the third sacral segment—was situated in a small mass of tissue located subcutaneously. The masses were apparently lipomatous in nature; they were somewhat movable. There was no radiation of pain on irritation of the structures. No other significant abnormalities were noted on examination.

Roentgenograms of the sacrum and coccyx showed a bony fusion of the sacrococcygeal joint and the segments of the coccyx, with angulation of 45 degrees to the left, at the mid-point of the coccyx.

She was seen at intervals during the following year, and, on two different occasions, procaine was injected into the masses of tissue in the sacral area. The tenderness was not completely eliminated following injection, although on both occasions there was a significant relief of pain and diminution of tenderness for from one to two weeks. Similar results were obtained on several occasions when she was treated elsewhere by procaine injections.

It was considered advisable to remove the soft-tissue structures. Under local anaesthesia, two transverse incisions were made. The masses consisted of oedematous lobules of fat tissue, situated underneath the deep fascia. These, together with small portions of apparently normal fat, were resected. The woman was promptly relieved of pain in the lower part of the back and coccyx. She is now able to sit normally and pursue her ordinary activities. The period of postoperative observation was three months.

Observations on three additional patients revealed findings of a similar nature, the principal feature consisting of a variable degree of hyperalgesia of the soft tissues overlying the middle portion of the sacrum. In two of these, injection of procaine into the sensitive structures resulted in marked relief from pain for several days. It was thus established that the factor responsible for the coccygeal pain was an irritative lesion in the soft tissues of the sacral region.

COMMENT

An analysis of the five cases indicates that they have one combination of manifestations in common,—pain and tenderness of the coccyx with associated tenderness in the sacral region. The tenderness was elicited with marked regularity in the mid-sacral level, lateral to the mid-line. It was justifiable to conclude that the tenderness arose from soft-tissue structures, since it was eliminated by an injection of local anaesthetic into the sensitive areas. The only tissues which are likely to be affected by such injections are the layers of fat tissue underneath the deep fascia and, possibly, those situated superficial to the fascia. The potentialities of fat tissue as a source of noxious impulses has been demonstrated [4, 5, 6, 10, 11, 12, 21, 22]. Additional support for this conclusion is provided in this series in which one patient was subjected to operation and the others yielded the expected results from local anaesthetization. As a means of evaluating the influence of motion at the sacrococcygeal joint and between the segments of the coccyx, it is significant that in Case 2, a firm bony union was found between these structures. In this connection, Callander states that the whole coccyx may be ossified to the apex of the sacrum.

The observation that coccygeal pain can be eliminated by abolishing the primary source of the pain and without any direct intervention on the coccyx would tend to verify suspicions that the pain is referred. It is, therefore, of some importance to analyze the mechanism and the channels by which the pain is referred. Information on the afferent supply to bone is meager. Haymaker and Woodhall, using the charts of Dejerine, state only that the vertebrae are supplied by the posterior primary rami of the respective spinal nerves. Inman and Saunders have carried out an extensive investigation of sclerotomic innervation, including separate studies of the soft tissues and of the bony structures. These, however, provide no information on the nerve supply to the coccyx[13]. From an additional study of the pain charts of Inman and Saunders, it is noted that the superficial sclerotomic structures overlying the mid-sacral region are probably innervated by afferent components of the first sacral nerve. When hyperalgesic areas are located in the soft tissues of the mid-sacral level, as was evident in all cases here considered, the distribution of the referred pain and tenderness from that site is strikingly in conformity with the field established as the first sacral sclerotome. The relatively low incidence of coccygeal pain and tenderness associated with painful lesions elsewhere is in keeping with the assertion by Wolff and Wolf that referred pain need not, and usually does not, involve the whole segment of reference. With recognition of this characteristic, which is evidently acceptable, it may be understood why different portions of the sclerotome may be affected by pain from a common trigger point.

From the observations thus made, it would seem justifiable to conclude that the bony portion of the coccyx probably lies within the first sacral sclerotome; that coccygodynia may arise and persist as referred pain from a trigger point located elsewhere within the distribution of the first sacral afferent elements; that the most common site of the primary source of the pain consists of soft-tissue structures, probably fat tissue, in the mid-sacral region; and that coccygodynia so provoked may be relieved by elimination of the source of the pain.

From a survey of different features seen in connection with coccygodynia, the functional element is considered to be important among most investigators. It is of course possible to find a neurotic background in patients so afflicted. Observations made in the small series here studied would seem to indicate that both the psychic manifestations, when present, and the coccygeal pain are direct results of the primary source of pain in the fat tissue.

On the basis of these observations, the interpretation of coccygodynia as referred pain and tenderness appears to be adequate for the purpose of establishing the mechanism of development and also providing a foundation for rational treatment.

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A RARE FORM OF MALIGNANT JOINT TUMOR

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TRANSLATED FROM THE GERMAN BY HENRY MILCH, M.D., NEW YORK, N. Y.

All joint tumors, whether benign or malignant, and regardless of their clinical appearance, may be recognized by the ontogenetic characteristic that they are derived from mesodermal tissue. If a joint tumor presents a structural configuration and cellular forms which cannot be of mesodermal derivation, diagnosis of a tumor originating from joint structures may be excluded, even if the tumor is grossly restricted to the joint area. This is well illustrated in the following case history.

A man, thirty-three years old, in a poor state of nutrition, was admitted to the Hospital because of pain in the left knee. The patient's father had died of pulmonary tuberculosis.

At the age of thirteen the patient had been operated upon for a swelling in the left scrotal region. Similar swellings, which developed above the left supra-orbital ridge and along the inner aspect of the left thigh, healed after treatment by radium.

At the age of ten a swelling had developed in the left knee which caused no difficulty in the beginning and occasionally subsided. About a year after onset, there was some enlargement of the knee, for which the patient was sent to a resort for salt-water bathing. There an operation of undetermined nature was performed. However, the condition of the knee became gradually worse, so that the knee could not be moved or bear weight without pain.

FIG. 1-A

FIG. 1-B

Fungous tuberculosis of the left knee of twenty-three years' duration in a man thirty-three years old. During the past year bilateral deep ulcerations have extended from the sinus openings.
Fig. 1-A: Medial view.
Fig. 1-B: Lateral view.

Upon the first admission treatment by extension was followed by the development of six or seven sinus tracts which secreted a thin yellowish pus. During the next few years these sinus closed and new openings appeared. Treatment consisted of intermittent roentgen irradiation and exposure to the sun as weather permitted. Gradually these bilateral sinus became larger, so that large wound surfaces were present. The swelling increased considerably and the patient complained of a drawing and burning pain. Hospitalization again became necessary at this time.

Clinical and Roentgenographic Findings

The left knee joint (Figs. 1-A and 1-B) was fusiform in outline and was somewhat under 39 centimeters in diameter. The muscles of the thigh and leg were extremely atrophic. There was a large open fistula on the

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FIG. 2

Roentgenogram showing diffuse destructive process extending into the femoral and tibial diaphyses, with disappearance of joint space. The cortices of both metaphyses and diaphyses are "feathered". The retrocapsular tissue is thickened.

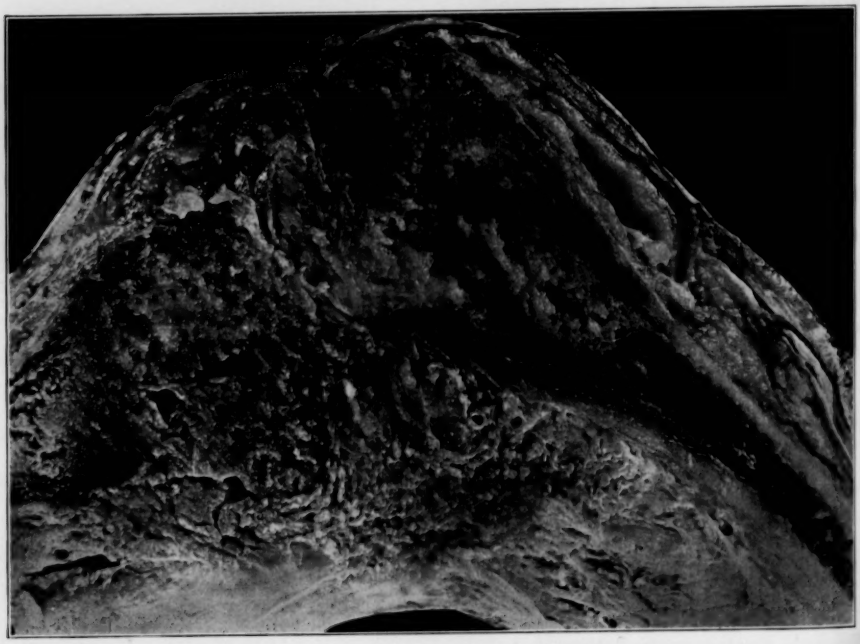

FIG. 3

Sagittal section through amputated knee. The femoral and tibial epiphyses are without distinct demarcation and are infiltrated with grayish-red tumor tissue. The cortex is thinned out and the joint space is completely filled with tumor tissue.

FIG. 4

Shows horny squamous-cell carcinoma spreading into the inflamed connective tissue.

inner aspect of the knee. Distal to this there was a hand-sized defect. A dense grayish-white tissue, covered with a greenish-yellow exudate, projected from the ulcerated area. On the lateral aspect of the knee (Fig. 1-B) there was a similar ulcer, larger than the first (11 by 9.5 centimeters), with a dense grayish-white floor into which several fistulae opened. A walnut-sized, white nodule which was adherent to the skin projected distally to the tibial tuberosity. The knee joint, fixed by fibrous ankylosis in flexion of 130 degrees and dorsal subluxation, was painful on the slightest motion.

Roentgenographic examination of the knee (Fig. 2) disclosed extensive destruction of the articular ends of the femur, the tibia, and the patella. The bone substance was irregularly porotic and sclerotic, giving the occasional appearance of cyst formation. The patella was united to the femur.

From the clinical and roentgenographic appearance, the tumor was judged to be malignant. Because the inguinal glands were enlarged but not confluent and the lung fields were clear, amputation in the middle third of the femur was undertaken, with primary closure of the wound.

Pathological Findings

In the sagittal section of the amputated knee (Fig. 3), the outlines of the femur and the tibia were only indistinctly seen. The compact bone was thinned out and the spongiosa was replaced by a reddish-gray soft tissue which filled the entire joint space. Histological examination disclosed a horny, squamous-cell carcinoma (Fig. 4), infiltrating a chronically inflamed connective tissue which contained typical tubercles, and a sinus tract lined with non-specific granulation tissue.

Postoperative Course

Several days after operation, a purulent discharge appeared from the wound which was then opened and drained. After two months of treatment the infection was controlled and the wound began to heal. At his own request, the patient was discharged from the Hospital. It was intended to excise and examine one of the hard inguinal glands at a later date. The patient, however, did not return until two years after his discharge. In the interval, he had been quite free of symptoms. About six months before his readmission, he had begun to notice a swelling of the right leg, accompanied by nausea and vomiting. For a few days prior to his hospitalization there was repeated vomiting together with gradual deterioration of the general condition.

Examination revealed non-protein nitrogen of 149.94 milligrams per 100 cubic centimeters. Uraemia was diagnosed, and shortly thereafter the patient died of pulmonary oedema. Autopsy disclosed an extensive

amyloidosis of the kidneys with slight amyloid degeneration of the liver and spleen. There was no evidence of any metastasis from the joint tumor removed two years before.

CONCLUSIONS

Though the history and the specific changes indicate the tuberculous nature of the joint affection, the histological examination leaves no doubt that the joint tumor was a squamous-cell carcinoma. The sequence of events would seem to indicate that in childhood this patient had suffered from a disseminated caseous glandular tuberculosis which eventuated in tuberculosis of the knee with chronic fistula formation. The extent of the influence of heliotherapy and roentgenotherapy on the development of the carcinoma cannot be appraised, but it is certain that under their influence the epithelium grew rapidly along the sinus tracts to the very center of the joint. This led to the formation of small islands of squamous epithelium, which under the constant irritation of the purulent secretion developed into a malignant tumor. Since the tumor arose from healthy tissue secondarily stimulated to malignancy by locally determined factors, it must be differentiated from a primary as well as from a metastatic tumor.

The continued effect of repeated heliotherapy and x-ray irradiation with the chronic irritation of the tuberculous fistulae may account for malignant degeneration such as is seen in carcinomatous degeneration of skin lupus after roentgenotherapy. Beck, Küttner, Marsch, and others have suggested a possible relationship between the appearance of joint sarcoma and previous x-ray treatment of joint tuberculosis.

The clinical experience in this case points to the conclusion that resection should be undertaken as soon as growth has ceased in all cases of chronic pyogenic joint disease with fistula formation. In older people with extensive involvement or in those in whom there is unsatisfactory healing, amputation should be undertaken at the very outset.

NOTE: The author wishes to thank Dr. Henry Milch for his most painstaking translation of this article.

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DENERVATION OF THE ANKLE JOINT

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Denervation of the ankle joint is a new and relatively simple approach to the old problem of pain in the ankle resulting from traumatic arthritis. The senior author became interested in this problem several years ago and devised an operation to denervate the ankle joint. The anatomy and the operative procedure will be discussed in detail, but the purpose of this operation and its possible complications should be considered first.

Many patients with pain in the ankle resulting from traumatic changes do not exhibit arthritis of a sufficient degree to necessitate fusion. Other patients cannot be subjected to a major surgical procedure and a prolonged period of immobilization either because they are poor operative risks or because of economic reasons. Still others cling to joint motion at any cost, seeking only some relief from pain. Unfortunately, conservative measures—such as arch supports, shoe corrections, and physical therapy—are usually of little value.

Neurectomy has been used in the treatment of pain in the hip joint with varying degrees of success [4, 23, 24, 25]. It has also been used for the elbow by Bateman. Sallick and Blum in 1948 divided the sural and tibial nerves in an attempt to eliminate the pain resulting from old fractures of the os calcis. Of seven patients who were totally disabled, four returned to full work after the operation. Although the intrinsic muscles were paralyzed by this procedure, this apparently did not result in much disability.

In so far as can be determined, no one has reported on the use of denervation in the treatment of the painful ankle joint. This seems somewhat surprising, for the ankle is almost subcutaneous and its nerve supply unusually accessible. Moreover, the pain from pathological changes here is well localized, and the nerves dealt with do not have the great importance of those elsewhere as, for example, the median nerve at the elbow. However, it should be noted that even here referred pain may be a factor as indicated by Kernwein and Kelikian.

In considering this method of treatment, several questions must be answered: For what kind of joint pain is the operation of neurectomy indicated? Will neurectomy interrupt the nerve supply to the fibrous capsule and synovial membrane or to the subchondral bone or to both? This poses the problem of the origin of joint pain.

The articular cartilage is generally agreed to be devoid of nerve fibers and therefore anaesthetic. The synovial membrane, on the other hand, is commonly believed to be sensitive to pain. The subsynovial tissues, as well as the fibrous capsule, contain not only free nerve endings but also rake-like endings similar to the terminal cylinders of Ruffini which may respond to pressure from proprioceptive sensation. Gardner [9, 14], in his exhaustive studies of other joints, has reported that such complex proprioceptive endings as the Pacinian corpuscles have rarely been found in the region of the capsule.

While cortical bone is relatively insensitive to pain, cancellous bone has been found sensitive to pain stimuli. That the pain in these regions may have a vascular origin must be taken into consideration, for Woollard, in experiments with animals, found that the blood vessel walls contained both medullated and non-medullated nerve fibers. These fibers were most numerous in the smaller arteries.

In their clinical studies, Bazett and McGlone found that puncture of vessels, especially of the smaller arteries, produced pain which was intense, deep, unbearable, and

nauseating. This and the work following Leriche's introduction of periarterial sympathectomy has led to the conclusion that the nerves in the blood vessel walls are afferent and sympathetic. While these fibers accompany the larger peripheral vessels for a short distance, the smaller vessels receive their supply from the somatic nerves in the region. Authorities such as Gask and Ross feel that vessels are as sensitive to tension as are the viscera, and that tension causes a burning type of pain.

Such a complex nerve supply, involving as it does the capsule, synovial membrane, cancellous bone, and blood vessels, would seem to make denervation impractical, especially when one considers Gardner's findings in such joints as the knee [10], hip [11], elbow [13], and shoulder [12]. According to him, nerve endings tend to be grouped in those regions of the joint capsule most subject to pressure or motion, but any one region of a joint is supplied by more than one nerve. Moreover, the point where a nerve enters the joint does not necessarily predetermine its local distribution. Finally Bateman found that in the elbow, the area of distribution of any one nerve is not constant. There was considerable variation in the size and importance of the branches in the different patients and specimens studied.

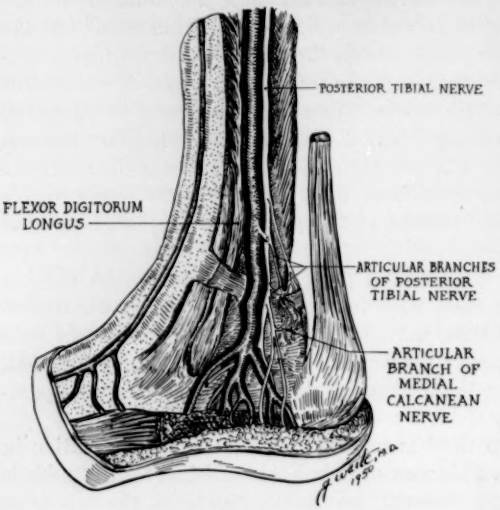
POSTERIOR TIBIAL NERVE
FLEXOR DIGITORUM LONGUS
ARTICULAR BRANCHES OF POSTERIOR TIBIAL NERVE
ARTICULAR BRANCH OF MEDIAL CALCANEAN NERVE

FIG. 1

Dissection study of the tibial nerve and its articular branches.

Fortunately, this complex problem resolves itself if one recalls several points. The epiphyses receive their blood supply from the articular arteries [22]. These vessels enter the bone through the capsular attachments. Few of the metaphyseal vessels with their accompanying nerves invade this region, since they tend to remain as end arteries, their capillaries forming hairpin turns at the site of the original epiphyseal synchondroses. Gardner [14], in studies of other joints, has shown that nerves pierce the joint capsule with the articular vessels and accompany them not only into the synovial region but also into the adjacent epiphyses which form the articular surfaces of the joint. Some of these nerve branches are located in the adventitia of these vessels.

One may, therefore, conclude that it makes little difference where the major source of the pain lies. Regardless of its origin, whether it be in the subchondral bone, in the synovial lining, in the fibrous capsule, or in the blood vessels, denervation will be effected by division of all articular nerves. It should be noted that surrounding structures such as tendons, deep fascia, subcutaneous tissues, and the skin are not denervated, and patients with painful pathological conditions affecting these structures will not be relieved by this operation.

Still another problem now presents itself. Will denervation result in a neuropathic or Charcot joint? Eloesser's classic work on the production of neuropathic joints, in 1917, demonstrated that, experimentally at least, more is needed than simple joint anaesthesia produced by local denervation. He divided the posterior roots which were distributed to the hind legs of sixty-nine cats and followed forty-two of these for periods of three months to three years. From these experiments it may be concluded that four factors must be present simultaneously to produce a neuropathic joint. These are, (1) loss of the muscle

coordination which protects a joint from moving beyond the extremes of normal motion, (2) loss of position and of tactile sense, (3) unrecognized injury, and (4) continued activity.

The clinical findings in tabetic patients bear out Eloesser's belief that more than one factor is involved in the production of neuropathic joints. For, while 90 per cent. of all neuropathic joints are due to tabes dorsalis, such joints develop in only 5 to 10 per cent. of all patients with tabes dorsalis [5]. In syringomyelia, Charcot joints develop in 20 per cent. of cases [3].

To test this conclusion further, several reports on neuropathic joints resulting from peripheral-nerve injury were reviewed. These confirmed the finding that the four factors which produce a neuropathic joint must be present simultaneously. Thus Kernwein and Lyon report the case of a man, twenty-two years old, who suffered complete severance of the sciatic nerve, but who learned to walk on the affected limb unaided. The only joints theoretically capable of neuropathic change in such a condition would be the ankle or joints distal to it. This proved to be the case. Within fifteen months of the date of injury, neuropathic changes in the ankle and tarsal joints had developed.

Another report of neuropathic joint changes following peripheral-nerve injury is that of Duncan in 1922. His patient was a man about forty-two years old, who had sustained a brachial plexus injury about four years previously. Apparently the posterior roots had been avulsed, while the anterior roots remained intact. He had full muscle power, but lacked sensation in the entire arm and in part of the shoulder girdle as well. He was found to have a typical neuropathic arthritis of the wrist.

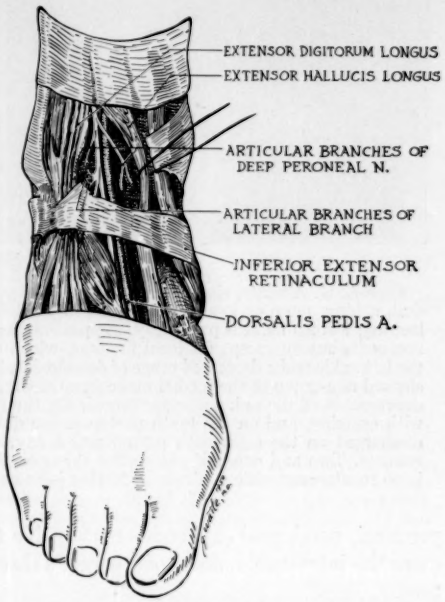

FIG. 2

Dissection study of the deep peroneal nerve and its articular branches.

Clinically, one finds that neurectomies on other articulations have not been followed by neurotrophic joints. Such writers as Kaplan specifically mention that repeated roentgenograms revealed no evidence of trophic joint changes. There should be little danger of trophic changes in the skin or its derivatives if a sensory nerve to the distal cutaneous regions is accidentally transected, for, as Tinel stated, even complete interruption of a nerve causes either minimal trophic disturbances or none. On the contrary, it is neuritic irritation which brings about changes in the skin, nail, and hair, as well as capsular and aponeurotic contractures which develop secondarily. Many others have since concurred in this finding, including Dean Lewis and Haymaker and Woodhall. Further support is found in the report by Corlette and that by Smith, who successfully brought about closure of irritable ulcers by cutting all tissues from skin to bone and thus locally denervating them.

While neuropathic changes have not occurred in other denervated joints, one might feel concern for the safety of the ankle, subject as it is, anatomically, to such complete denervation. However, Laskey and Silbert, Smithwick and White [28, 29], as well as Smith report favorably on performing denervation operations on a number of patients with Buerger's disease. These were not merely articular neurectomies but often consisted in a complete transection, either chemically or mechanically, of the tibial, deep and superficial

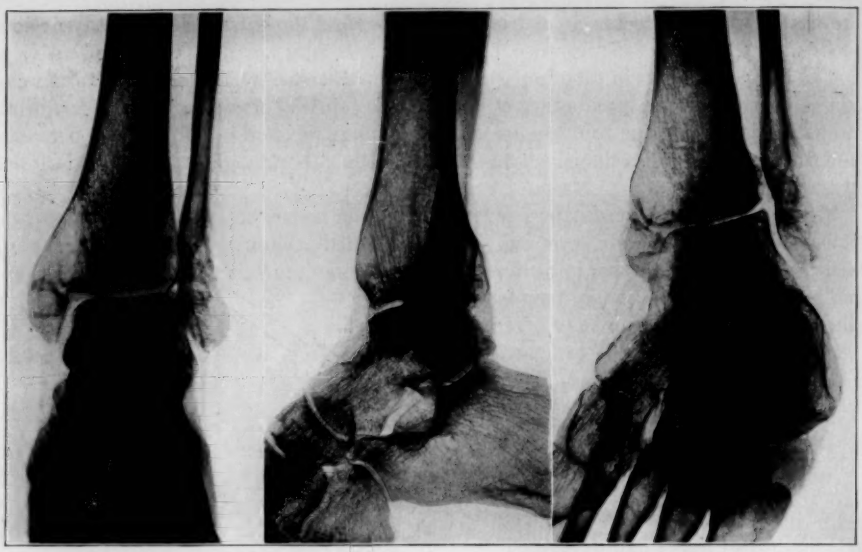

FIG. 3–A FIG. 3–B FIG. 3–C

Case A. G. A white, single female, thirty-four years old, was admitted to the Hospital because of a dull, aching, more or less constant pain in the left ankle, which increased in intensity upon weight-bearing. Fifteen months previously, the patient had fractured her left ankle. Physical examination was non-contributory except for local findings, which consisted of tenderness over the anterior aspect of the left ankle and a decreased range of dorsiflexion. There was no evidence of vasomotor changes. X-rays showed non-union of the medial malleolus. On the second day of hospitalization anterior and posterior denervation of the ankle was performed. On the fifth postoperative day the patient was ambulatory with crutches, and on the tenth postoperative day full weight-bearing was started. The patient was discharged on the eighteenth postoperative day, walking with full weight-bearing and without discomfort. Two and one-half years after the operation the patient is completely asymptomatic. There is no roentgenographic evidence of further joint changes since the previous examinations.

peroneal, sural, and saphenous nerves. No trophic changes were seen. Instead, in many cases the intractable ulcers of Buerger's disease healed, and the patients became ambulatory.

INNERVATION OF THE ANKLE

The innervation of the ankle has not been described in detail in any of the accepted textbooks of anatomy. The nerve supply has been consistently attributed to branches from the saphenous and tibial nerves, and from a lateral division of the deep peroneal nerve. Details of the origin and location of these articular branches are lacking.

Dissections of the ankle region have been performed on twenty specimens. Four of these were embalmed, and sixteen were amputated lower extremities.

These dissections have revealed the following patterns of innervation (Figs. 1 and 2):

1. Branches of the saphenous nerve ramify over the medial malleolus. These do not appear to innervate the joint proper.

2. Branches from the deep peroneal nerve extend to the anterior joint capsule. These may arise as medial and lateral filaments coming off above the bifurcation of the nerve to its terminal branches. Multiple small branches also arise from the lateral terminal branch just below the bifurcation and turn proximally into the joint. A small branch may also arise from the medial terminal branch just distal to the latter's origin from the main nerve.

3. Branches from the tibial nerve supply the posterior joint capsule. One or two branches arise from the posterolateral aspect of the nerve approximately two or three centimeters above the joint and course downward and posterolaterally to ramify on the

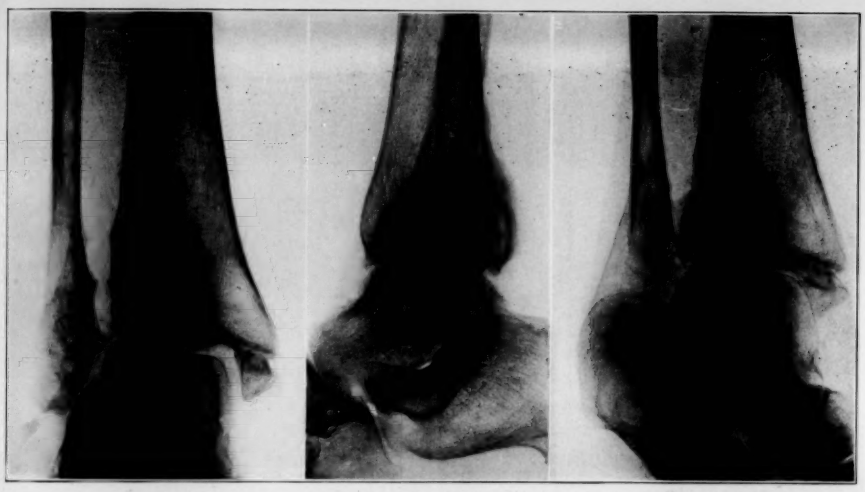

FIG. 4-A FIG. 4-B FIG. 4-C

Case I. H. A white male, fifty-three years old, was admitted to the Hospital because of pain and swelling of the right ankle for a period of six months. Nine months before admission, the patient had sustained a fracture of the right ankle which had been immobilized in a cast for eight weeks. There was swelling of the ankle which diminished with rest and increased with ambulation. Local physical examination revealed a + + + pitting oedema of the right ankle without evidence of vasomotor imbalance. Dorsiflexion was limited to 5 degrees, but there was good plantar flexion. Inversion of the ankle caused a moderate amount of pain. Pain was present upon forced dorsiflexion. X-rays showed spreading of the ankle mortise and early degenerative changes. On the second day of hospitalization a local anaesthetic block of the lateral branch of the deep peroneal nerve and the tibial nerve about the ankle was performed. After this procedure the patient could walk with crutches without experiencing the pain previously present. This remission lasted for two hours. Tibial and deep peroneal neurectomies were performed on the following day. On the fifth postoperative day the patient walked with a cane, experiencing only a minimal amount of pain due to operative incisions. He was discharged on the fifteenth postoperative day. Ninety-five per cent. of his pain had been relieved, with only minimal discomfort over the lateral malleolus remaining. He was followed for a year, at which time he died from a bronchogenic carcinoma. At the time of his final hospitalization, he stated that he had experienced only minimal ankle pain and had been able to walk upstairs and downstairs without difficulty. He had walked as far as five miles without pain or swelling.

capsule. A transverse articular filament from the posterior branch of the medial calcaneal nerve courses posterolaterally over the joint capsule, supplying branches to the capsule and to the overlying fat pad in the supracalcaneal space. The nerve passes posteriorly to the flexor hallucis longus tendon but gives off capsular branches which circumvent this interposed structure. A very small and inconstant branch to the joint arises from the lateral plantar nerve soon after the latter separates from the medial plantar nerve. A branch from the tibial nerve, the interosseous crural, passes distally in the interosseous membrane near the peroneal artery. It supplies the inferior tibiofibular joint. This branch is a small filament and does not appear to innervate the ankle joint proper.

These findings indicate that the major portion of the nerve supply to the ankle joint is derived from the tibial and deep peroneal nerves, and the distribution is concentrated over the anterior and posterior portions of the capsule. The nerves to be sectioned are thus accessible through two incisions, one posteromedial, the other anterior.

It should be emphasized that filaments to the muscles and tendons about the ankle joint which arise from these two main nerves are not disturbed in these dissections. The majority of these fibers, which are probably proprioceptive, leave the main nerve stems above the level of the articular nerves.

It would also be interesting to have anatomical studies using serial microscopic sections of foetal and adult ankle joints comparable to Gardner's studies of the knee, hip, shoulder, and elbow [10, 11, 13, 12]. Additional information might possibly be obtained by inject-

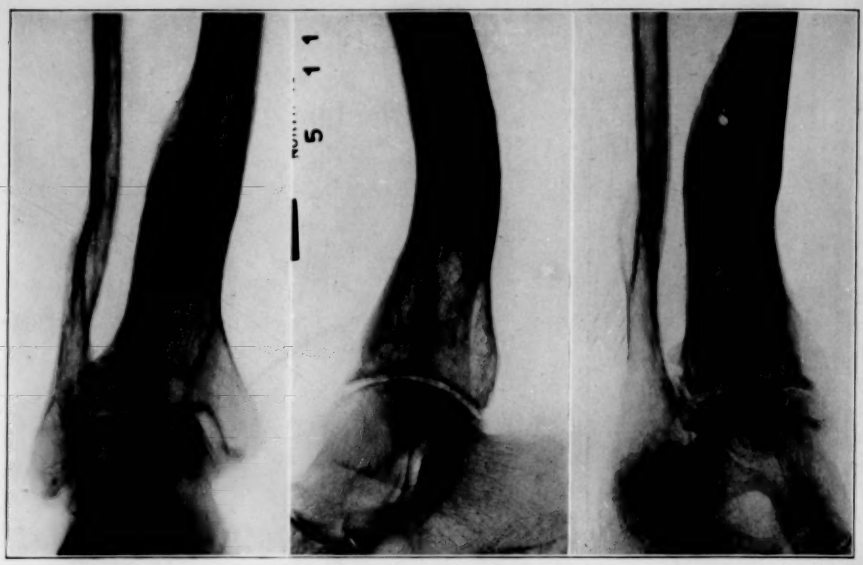

FIG. 5-A FIG. 5-B FIG. 5-C

Case B. H. A white housewife, fifty-four years old, was admitted to the Hospital because of severe pain in the right ankle for six months before admission. She had sustained a fracture of the right ankle in 1920, but she had been asymptomatic for twenty-seven years. During the last few years before admission, however, she began to have increasing pain in the ankle. For six months before admission, she had experienced severe ankle pain and was unable to bear full weight. There was local swelling after walking. Physical examination revealed a + + pitting oedema of the ankle, with tenderness over the anterior and posterior aspects of the joint. Motion was painful, and its range was limited to 5 degrees of dorsiflexion and 15 degrees of plantar flexion. X-ray showed malunion of an old fracture of the distal end of the tibia and fibula with traumatic arthritis of the ankle joint. A posterior and anterior denervation was performed and the patient was discharged on the third postoperative day after an uneventful course. The period of follow-up has not been long enough for evaluation at this time. Nine months after the operation, this patient was walking with very little discomfort and minimal oedema after a day of weight-bearing.

ing neurophilic dyes into the joint cavity of patients on whom an elective amputation is to be performed.

OPERATIVE TECHNIQUE

The procedure of anterior and posterior denervation is done under general anaesthesia and takes about forty-five minutes. The use of a Campbell-Boyd or other tourniquet is essential for the dissection required in this procedure.

The approach to the tibial nerve is through a J-shaped incision made one finger-breadth posterior to the medial malleolus, with the shank of the J slightly anterior and parallel to the medial margin of the tendo achillis. The incision is carried through the subcutaneous tissues and the laciniate ligament (flexor retinaculum of the ankle). The tibial nerve may then be identified. It lies three-quarters of an inch beneath the skin and lateral to the flexor digitorum longus. Directly anterior and slightly superficial to the nerve are the tibial vessels. These in company with the nerve are bound together in the neurovascular bundle. The vessels must be guarded from injury. Directly posterior to the neurovascular bundle is the medial margin of the tendo achillis. The articular branches from the tibial nerve may be identified as they pierce the deltoid ligament, just above the terminal division of the tibial nerve into medial and lateral plantar nerves. The articular nerves are ligated and sectioned. It may be necessary to trace the origin of these branches to a point about three centimeters above the joint. The medial calcaneal nerve is proximal to the level of the flexor retinaculum along the medial margin of the tendo

achillis. The transverse articular branch arising from this is ligated and sectioned *.

In summary, complete division of all the branches of the tibial nerve to the ankle may be ensured by identifying the nerve at the point of its bifurcation, and isolating, ligating, and sectioning: (1) all nerves proximal to the point of bifurcation for a distance of three centimeters, and (2) all nerves distal to the point of bifurcation (along the medial and lateral plantar nerves) for a distance of two centimeters.

The approach to the deep peroneal nerve is through an S-shaped skin incision made over the anterior aspect of the ankle, midway between the malleoli and lateral to the extensor hallucis longus tendon (which may be palpated at a point one-half inch lateral to the tibial crest). The incision is carried through the subcutaneous tissue and superficial fascia. The lower border of the transverse crural ligament and the entire cruciate crural ligament are sectioned. The deep peroneal nerve may be identified between the extensor digitorum longus and the extensor hallucis longus tendons. The nerve is usually found lying laterally to the dorsalis pedis artery. Articular filaments can be identified just above the bifurcation of the nerve into medial and lateral terminal branches. It is necessary to sacrifice the entire lateral terminal branch to ensure complete denervation. This will sacrifice only the relatively unimportant action of the extensor digitorum brevis.

It should be emphasized that, in the closure of these wounds, great care must be taken to approximate the severed ends of the extensor retinaculum. This fascial band serves a very useful function in maintaining fixation of the extensor tendons as they pass to the dorsum of the foot.

An anterior and posterior neurectomy for pain in the ankle has been performed on three patients at the Buffalo General Hospital. For their case histories see Figures 3-A to 5-C.

SUMMARY

It is believed that effective denervation of the ankle joint can be accomplished by transection of the articular branches from the posterior tibial and deep peroneal nerves together with sectioning of the lateral terminal division of the deep peroneal nerve. The motor loss from such a procedure, involving only the extensor digitorum brevis, is negligible.

From the evidence at hand it would seem that development of a neuropathic joint is theoretically impossible. In practice, this has been borne out in denervation operations on other joints, including neurectomies for the entire lower leg and foot, which incidentally would render the ankle joint anaesthetic. There have been no reports in the literature of development of neuropathic joints following such operations.

The operation is not presented as a panacea. It will not replace arthrodesis as the method of treatment in the severe arthritides or in patients with instability of the ankle joint. The early success in the cases reported here is worthy of consideration. A relatively simple operation, effective in alleviating symptoms, may be substituted for fusion in selected cases.

The value of the procedure can be determined only by a more extensive series, which will also develop criteria for its use.

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* The posterior branch of the medial calcaneal nerve may also be sectioned for pain associated with calcaneal spurs. This procedure will be discussed in a later article.

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DISLOCATION OF THE HIP COMBINED WITH FRACTURE OF THE SHAFT OF THE FEMUR ON THE SAME SIDE*

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INTRODUCTION

Statistics

Fracture of the shaft of the femur combined with ipsilateral dislocation of the hip is a rare injury. Malgaigne in 1855 listed the types of combined fracture-dislocation which were found in 2,358 fractures treated at the *Hôtel Dieu* over an eleven-year period; his list does not include a single case of combined fracture-dislocation of the femur. Henry and Bayumi in 1934 reported on the one case which was observed in 9,945 fractures and dislocations treated over an eight-year period at the *Kasr el Aini* Hospital in Cairo. In 1948 Wiltberger, Mitchell, and Hedrick reported on another case, which was one of four seen in 496,700 patients over a period of thirty-one years at the Henry Ford Hospital in Detroit.

In a review of the literature [1–28] the authors found that nineteen cases have been reported and seven more have been mentioned. In addition the authors have observed or treated seven cases and have collected information on nine others by personal communication. This makes a total of forty-two cases.

Factors Influencing Recovery

Provided that the dislocation of the hip is recognized at the time of injury, the prognosis is favorable in these cases. Extensive fragmentation of the acetabulum or aseptic necrosis of the femoral head may, however, impair the final result. If the acetabulum is fractured, the prognosis varies with the type of fracture. Where there are large fragments which may be reduced by closed or open methods, the prognosis and the immediate results are good. In cases in which there is extensive fragmentation and damage to the articular cartilage, the prognosis is uncertain. A poor result may be inevitable in such severe injuries.

Aseptic necrosis, one of the complications most frequently encountered, may be prevented by protection from weight-bearing, which in dislocation of the hip combined with fracture of the femoral shaft is always a necessary measure. The necessity for open reduction in some cases may increase the incidence of aseptic necrosis, even when correct diagnosis was made immediately. Nevertheless, those hips in which the dislocation has not been reduced promptly are even more susceptible to this complication.

The importance of diagnosing dislocation of the hip at the time of injury cannot be stressed too much. In the forty-two known cases, the dislocation was recognized at initial examination in only fifteen. In seventeen cases it was definitely not recognized, and in the remaining ten cases we have no information as to when the diagnosis was made.

In the majority of those cases in which the dislocation was not discovered at initial examination, the diagnosis was not made until four to six months later. Failure of the femur to unite finally necessitated a search for the cause of the non-union, which frequently proved to be the unreduced dislocation of the hip.

A hip which has been out of joint for half a year presents a different and much more

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 16, 1950.

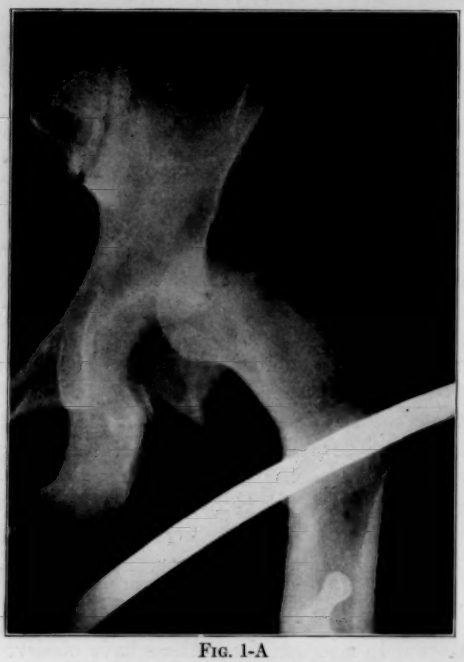

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Posterior dislocation of the left hip, with fracture of the rim of the acetabulum, diagnosed immediately. The patient also sustained a fracture of the left femur through the site of an old fracture which had been plated. A large posterior fragment of the acetabulum was displaced into the joint and blocked reduction. The fragment was connected to the ilium by a periosteal bridge. Because of a large superficial hematoma at the site of the fracture, with evidence of skin necrosis, early open reduction was considered inadvisable.

Fig. 1-B: Roentgenogram made after reduction. The acetabular fragment was restored to its anatomical position and secured with two Collison screws. The periosteal bridge was left intact. Reduction of the dislocation was accomplished without difficulty.

FIG. 1-C

Fig. 1-C: Twenty months after injury the patient had returned to military duty; he had no complaints and reported no difficulty. There was full range of motion of the hip and of the knee.

Figs. 1-D and 1-E: Anteroposterior and lateral views of the femoral shaft twenty months after injury.

FIG. 1-D FIG. 1-E

serious problem than a fresh dislocation. In the past, the outlook in old dislocations has been unfavorable. Moreover, an unreduced dislocation is often accompanied by nonunion of the femoral shaft. Since the treatment in old injuries differs greatly from that in fresh injuries, the two types of injuries will be discussed separately.

Factors in Diagnosis

Among the causes of failure to recognize dislocation of the hip at the initial examination, we must consider the frequent presence of other severe injuries. This is to be expected in view of the severity of the trauma necessary to cause such serious injury to the strongest bone and the strongest joint in the human body. Mr. Hackney [19] estimates that a force of 10,200 pounds is required to produce a dislocation of the hip. It is not surprising, therefore, that other vital parts of the body (such as the skull, the chest, and the abdomen) are frequently affected. The patient is likely to arrive at the hospital in critical condition, and preoccupation with efforts to save his life may be responsible for failure to pay adequate attention to the dislocation of the hip.

A comparative study of cases recorded from 1822 to the present [1–28] indicates that the discovery of the roentgen ray has not increased the percentage of correct diagnoses made at the time of the dislocation. Between 1822 and 1896 the dislocations were recognized in 50 per cent. of the 16 cases reported; from 1896 to the date of this report over 60 per cent. had been overlooked.*

Before the advent of the roentgen ray the physician had to rely on inspection, palpation, and manipulation to establish a correct diagnosis. Conscientious application of these physical means of examination should continue to aid in the proper evaluation of such injuries. More disability can be prevented by immediate recognition of the full extent of the damage than by the best reconstructive work attempted after a six months' delay.

CASE REPORTS

Fresh Injuries

CASE 1. The patient, a slender white male, twenty-one years old, had fractured his left femur four years before the accident which caused the combined fracture and dislocation. The first fracture had been treated

* Since this paper was submitted for publication, the senior author has found that he had overlooked a posterior dislocation of the hip for six weeks.

FIG. 2

Fig. 2: Case 2. Roentgenogram made three and a half years after injury, in which the patient had sustained a fracture of the femoral shaft, together with a posterior dislocation of the hip and fracture of the acetabulum. A closed reduction of the hip had been performed two days after injury and the fractured femur was treated by skeletal traction for three months. The patient returned to military duty eleven months after injury but was unable to continue.

Eighteen months after the injury the fracture of the femur was well healed and the range of hip motion was not limited except by 20 degrees of flexion.

Three and a half years after injury the patient had no complaints, but the roentgenogram reveals cystic changes in the head of the femur and narrowing of the joint space. (Official photograph, Photographic Section, Oliver General Hospital, Augusta, Georgia.)

by open reduction and fixation with a metal plate. It had united, with apparently excellent function, since he was admitted to military service. He was transferred to the authors' care three days after the second injury, which occurred when he was thrown from an automobile. He had sustained a fracture of the left femur through the old fracture site and through the metal plate, and a posterior dislocation of the hip with fracture of the posterior lip of the acetabulum (Fig. 1-A).

Skeletal traction through the condyles of the femur was applied upon admission. Check roentgenograms revealed improved position of the head in the anteroposterior view, but no actual reduction of the hip.

There was an extensive, fluctuant subcutaneous hematoma at the site of the fracture of the femoral shaft, and the skin appeared tense and dark; early operation on the femoral shaft was considered inadvisable.

Twelve days after admission and fifteen days after the accident, the hip was approached through a posterior muscle-splitting incision. The head of the femur was found dislocated under the gluteal muscles; and reduction was blocked by a large posterior fragment of the acetabulum, which had been displaced into the joint. This fragment was connected to the ilium by a periosteal bridge. The fragment was lifted out of the acetabulum and secured in anatomical position with two Collison screws, and the dislocation was reduced without difficulty. The intact periosteal bridge was left undisturbed (Fig. 1-B).

Forty days after the accident an open reduction of the femur was carried out, the plate and all easily accessible screws were removed, and the fracture was stabilized by a dual onlay tibial bone graft. The patient remained in traction for six months following the bone graft. Physical therapy was started one month after the second operation. At the time of removal of skeletal traction there was excellent range of motion of the hip and knee, and the patient was allowed to walk in an ischial weight-bearing caliper brace which he used for three months. He was discharged to resume military duty fourteen months after injury.

The patient was re-examined six months later. He had been performing full military duty without difficulty or complaints. He had full range of motion of the hip as well as of the left knee. No abnormality was noted except for the scars and one-inch atrophy of the left thigh. Roentgenograms revealed a normal hip and well-healed femur (Figs. 1-C to 1-E).

CASE 2. The patient sustained a fracture of the shaft of the femur in an automobile accident, together with a posterior dislocation of the hip, a fracture of the floor of the acetabulum, and a simple fracture of the left olecranon; he was in severe shock.

Skeletal traction through the tibial tubercle was applied immediately and the hip was reduced by manipulation under sodium pentothal two days later. The hip was flexed to 90 degrees, and one operator applied traction while the other applied direct pressure on the dislocated femoral head. The dislocation was reduced with an audible thud. The fractured olecranon required open reduction three weeks after the original injury. The fractured femur was treated by skeletal traction for three months. Following this, the patient became ambulatory and used a caliper brace with crutches for three months. Five months after injury motion of both hip and knee was still limited and the patient suffered discomfort in the hip after walking several blocks. He remained on limited weight-bearing for a total of nine months. He returned to military duty at his own request eleven months after injury and was sent to Saipan. However, he was unable to continue on full duty. He was returned to the Zone of the Interior eighteen months after the initial injury, at which time he was examined by the authors. He had a normal range of hip motion in all directions, except for 20 degrees of limitation of flexion. The range of knee motion was 180 to 70 degrees.

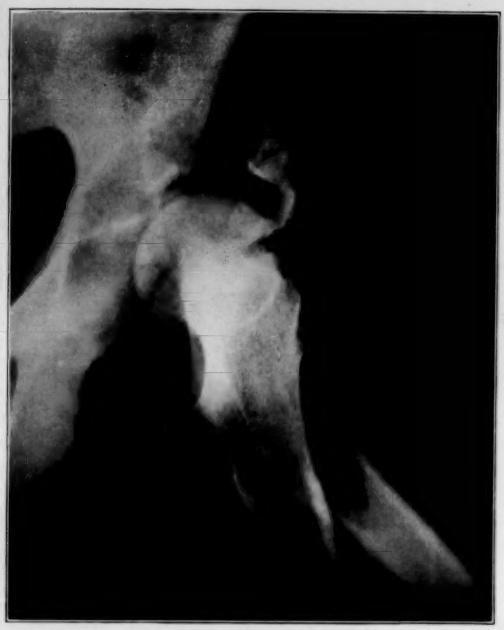

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. Roentgenogram showing a posterior dislocation of the hip, with extensive fragmentation of the acetabulum, and fracture of the femoral shaft at the juncture of the proximal and middle thirds.

Fig. 3-B: The femur was reduced through a lateral incision on the day of injury and was nailed with a Steinmann pin. The same exposure permitted replacement of the head of the femur. The fragments of the acetabulum remained displaced.

The patient was transferred to the authors' care three weeks later and was placed in Russell traction.

Fig. 3-C: Demonstrating flexion twenty weeks after injury. The patient was receiving physical therapy while being maintained in Russell traction. (Official photograph, Photographic Section, Oliver General Hospital, Augusta, Georgia.)

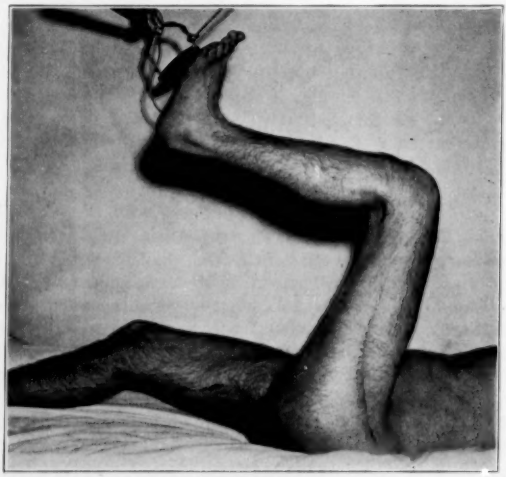

FIG. 3-C

The patient was re-examined by the Veterans Administration three and one-half years after his injury (Fig. 2). At that time his only complaint was slight limitation of motion of the left elbow.

CASE 3. The patient was a white male, twenty-six years old. He had collided with a car while riding a motorcycle and had sustained a comminuted fracture of the left acetabulum with a posterior dislocation of the hip and fracture of the shaft of the femur at the juncture of the proximal and middle thirds (Fig. 3-A).

Open reduction of the hip and femur through a lateral incision was performed on the day of injury. The reduction of the femur was maintained by an intramedullary Steinmann pin (Fig. 3-B). No attempt was made to reduce the fragments of the acetabulum. The patient was transferred to the authors' care three weeks after this operation and was placed in Russell traction. Fifteen weeks after injury the patient was still in traction, the dislocation had been reduced, and the femur was clinically solid. The range of motion of the knee was from 180 to 120 degrees. The range of

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4. Roentgenogram made on the day of injury, in which the patient sustained a posterior dislocation of the hip and a fracture of the femoral shaft.

Fig. 4-B: The hip was reduced on the day of injury; the fracture of the femoral shaft was reduced seven days later and two Lane plates were applied.

hip motion was limited by the Russell traction, but there was excellent lateral motion, rotation, and flexion (Fig. 3-C).

CASE 4. (Courtesy of Dr. Sidney J. Schafer, Wesley Memorial Hospital, Chicago.) The patient was a white male, forty-three years old, who was hit by a truck, sustaining a posterior dislocation of the hip and fracture of the middle third of the femoral shaft (Fig. 4-A).

The dislocation was reduced on the day of injury by manipulation under anaesthesia; seven days later the fracture of the shaft of the femur was reduced and two Lane plates were applied (Fig. 4-B). After nine months the patient refractured the femur and underwent another open reduction with bone graft. Following this the femur healed. The patient became ambulatory, with a full range of motion in the hip and no pain (Fig. 4-C).

Roentgenograms taken thirty months after the injury revealed some increased density of the head apparently secondary to aseptic necrosis. The patient still had a full range of motion and no pain (Fig. 4-D).

CASE 5. (Courtesy of Colonel Milton S. Thompson.) The patient was a white male thirty-two years old who was injured in an automobile accident. He sustained a posterior dislocation of the left hip and a simple transverse fracture at the juncture of the proximal and middle third of the left femur (Fig. 5-A), as well as a complete fracture of the mandible, and injury to the left sciatic nerve.

Attempts at closed reduction of the dislocation by skeletal traction on the proximal fragment of the femur were unsuccessful. Open reduction was performed without difficulty. The fracture was plated and was reinforced by iliac grafts (Fig. 5-B). Convalescence was uneventful and the foot-drop recovered. However,

FIG. 4-C

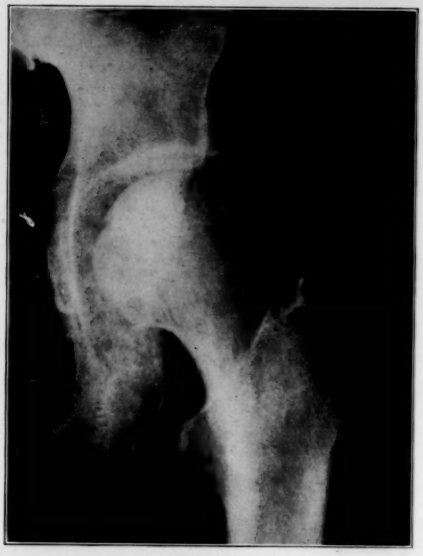

FIG. 4-D

Fig. 4-C: Nine months after injury the hip had a normal appearance. At this time the patient refractured the femur; an open reduction, with bone graft, was performed. The fracture united and the patient became ambulatory, with a full range of hip motion and no pain.

Fig. 4-D: Thirty months after the injury there is some increased density of the head apparently secondary to an aseptic necrosis.

a postoperative myositis ossificans developed, which required excision of the newly formed bone nine months after injury.

Two years after injury the patient had 110-degree flexion of the hip, normal rotation, abduction, adduction, and extension (Fig. 5-C). He is employed as a railway laborer.

CASE 6. (Courtesy of Major R. C. Rounds, Medical Corps, United States Air Force.) The patient was observed overseas. Both fracture of the femur and dislocation of the hip were recognized immediately. An attempt at closed reduction of the dislocation was unsuccessful. An open reduction of the fracture of the femoral shaft was then carried out, and during the operation an attempt was made to reduce the dislocation by direct manipulation of the proximal fragment with a lion's jaw forceps. This attempt was also unsuccessful and the patient was evacuated to the Zone of the Interior for treatment. No further information about the patient is available, but the case is reported because it is of interest that open reduction of a dislocation of the hip may become necessary even in fresh and immediately recognized injuries.

CASE 7. The patient was a white male, twenty-eight years old. A truck in which he was riding overturned, and he sustained a compound, comminuted fracture of the left femur at the juncture of the middle and distal thirds. There was also present a simple comminuted fracture of the left femur at the juncture of the middle and distal thirds, as well as a fracture of the right acetabulum, together with a posterior dislocation of the right hip and a displaced fracture of the posterior lip of the right acetabulum. The right supra-orbital ridge was also fractured. The patient was in severe shock.

The dislocation of the right hip was not discovered until one month after injury, but it could then be reduced by manipulation. The left femur was plated at the same time. The right femur showed delayed union after five months and was treated by open reduction with a bone plate and tibial graft. This femur was kept immobilized in traction, and then in a spica for a total of ten months. The patient then became ambulatory and wore a brace for another thirteen months.

He was examined by the authors two years after injury. At that time examination of the right hip revealed a flexion deformity of 15 degrees, and two inches of shortening. Hip flexion was possible to 95 degrees, adduction was limited by 5 degrees, and abduction by 20 degrees. The range of motion of the right knee was from 180 to 135 degrees. The patient had no subjective complaints and was ambulatory without support.

Roentgenograms were taken by the Veterans Administration four years after the accident (Fig. 6-A). The right hip showed some posterior subluxation. The right femur was well aligned, but a line of radiolucency,

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 5. The patient sustained a posterior dislocation of the left hip and a simple transverse fracture of the shaft at the juncture of the proximal and middle thirds. Open reduction was performed after skeletal traction on the proximal fragment had failed to reduce the dislocation. (Official photograph, Brooke General Hospital, United States Army.)

Fig. 5-B: The fracture was plated and iliac bone grafts were used for support. A postoperative myositis ossificans developed. (Official photograph, Brooke General Hospital, United States Army.)

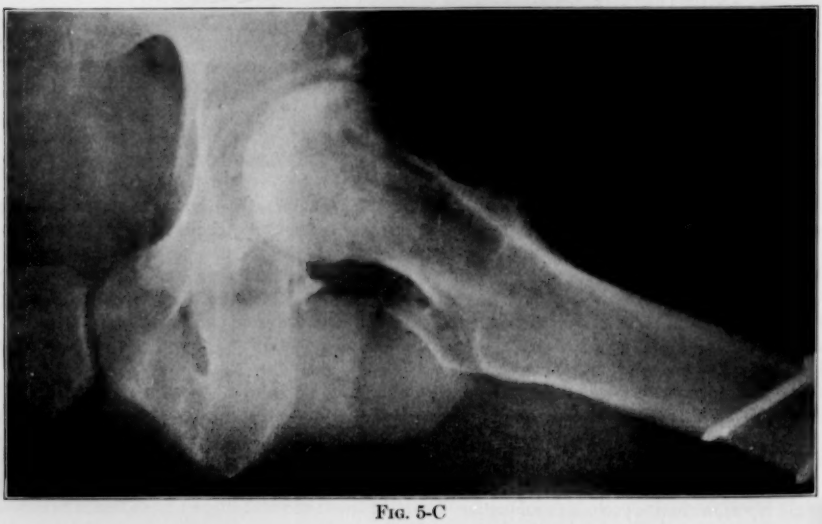

FIG. 5-C

Fig. 5-C: Roentgenogram made two years after injury. Flexion of the hip is 110 degrees, rotation, abduction, adduction, and extension are normal. At this time the patient was working as a railroad laborer. (Official photograph, Brooke General Hospital, United States Army.)

FIG. 6-A

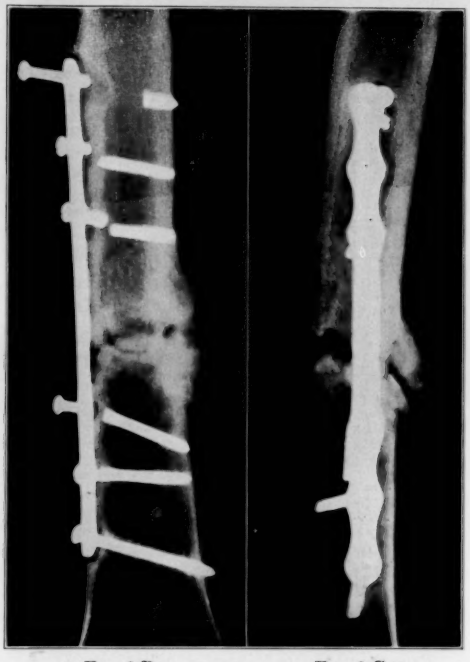

FIG. 6-B

FIG. 6-C

Figs. 6-A, 6-B, and 6-C: Case 7. Roentgenograms made four years after injury, in which the patient had sustained a posterior dislocation of the right hip, a displaced fracture of the posterior lip of the acetabulum, and a fracture of the supra-orbital ridge, together with a fracture of the ipsilateral femur at the junction of the middle and distal thirds. There was also a compound comminuted fracture of the left femur at the juncture of the middle and distal thirds.

The dislocation of the hip was discovered one month after injury and was reduced by manipulation, and the fracture of the contralateral femur was plated at the same time.

The patient became ambulatory ten months after the injury with an ischial weight-bearing caliper which he wore for an additional thirteen months.

Fig. 6-A: Roentgenogram made twenty months after the injury. The hip is asymptomatic in spite of flexion deformity of 15 degrees, posterior subluxation, and narrowing of the joint space.

Figs. 6-B and 6-C: Anteroposterior and lateral roentgenograms of the right femur twenty months after injury. There is shortening of 2 inches and moderate atrophy of the thigh, but the fragments are in good alignment, and in spite of the non-union and four broken screws the patient had no complaints.

with adjacent sclerosis, was present at the fracture site, indicating non-union. The three screws anchoring the bone plate to the distal fragment, as well as one screw of the proximal fragment, were broken (Figs. 6-B and 6-C).

This case falls into an intermediate group inasmuch as the dislocation was not discovered for one month. It is listed with the fresh cases since it was still possible to reduce the dislocation by closed manipulation one month after injury.

Unrecognized Dislocations

CASES 8 and 9. Dr. Lorenz Böhler has observed two cases with bilateral fractures of the femora, and unilateral dislocation of the hip which had remained unrecognized. In both of these cases open reduction of the dislocation was necessary. The results were not considered satisfactory since the hips became stiff. Because of unfavorable experience with open reduction of old dislocations, Dr. Böhler advises subtrochanteric osteotomy rather than reduction. This procedure has given satisfactory results in his hands.

CASE 10. (Courtesy of Major Roy C. Rounds, Medical Corps, United States Air Force.) The patient was injured in an automobile accident. A fracture of the femur was recognized and treated, and the patient was discharged from the hospital thirteen months after his injury. When he became weight-bearing there was instability of the hip and considerable shortening of the extremity. Roentgenograms revealed a persistent posterior dislocation of the hip. Open reduction was then undertaken. Upon exposure of the head of the

FIG. 7-A

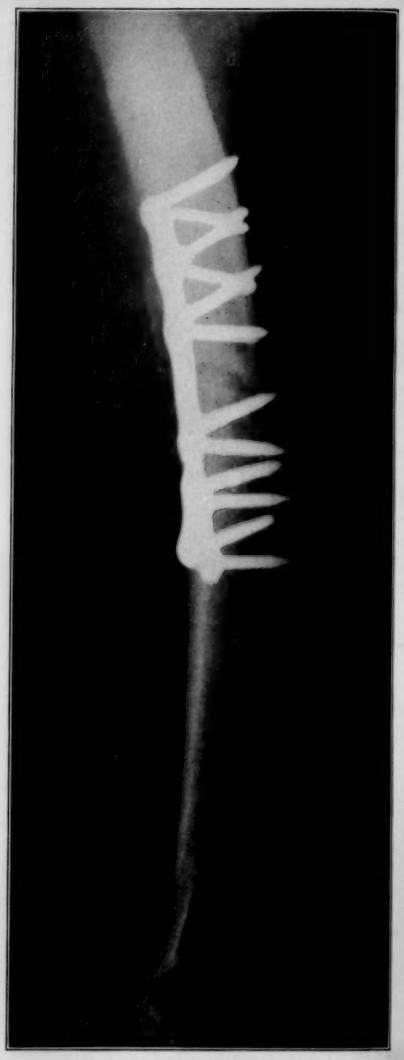

FIG. 7-B

Figs. 7-A and 7-B: Case 15. The patient sustained a fracture in the middle third of the femur and a posterior dislocation of the ipsilateral hip, as well as paralysis of the sciatic nerve. The dislocation was recognized immediately, and the patient was placed in skeletal traction. Anteroposterior roentgenograms appeared to show that the dislocation had been reduced.

Four months after injury the patient was transferred to the authors' care. There was still non-union of the femur without alignment, and a persistent dislocation of the hip was revealed.

Fig. 7-A: Roentgenogram made three months after open reduction, performed four months after the injury. Skeletal traction was applied before reduction, in order to secure as much muscle lengthening as possible. The reduction was then begun through a posterior approach but could not be effected until the muscle attachments about the hip were freed by osteotomy of both trochanters. There was narrowing of the joint space and evidence of an aseptic necrosis. A screw was used to reattach the greater trochanter. (Official photograph, Photographic Section, Oliver General Hospital, Augusta, Georgia.)

Fig. 7-B: The femur was plated during the same operation through an extension of the posterior approach to the hip. The bowing is the result of shortening and of the tension of the soft tissues. The fracture healed without further difficulty. (Official photograph, Photographic Section, Oliver General Hospital, Augusta, Georgia.)

femur, the surgeon found extensive degeneration of the articular cartilage which peeled off the underlying bone. The joint cavity was filled with scar tissue. Partial reduction by traction and manipulation was possible after all the articular cartilage had been removed. The hip was arthrodesed and reinforced with bone grafts. The patient could not be followed.

CASES 11 and 12. (Courtesy of J. R. Armstrong, Air Wing Commander, Royal Air Force.) These patients both had an old unreduced dislocation of the hip associated with fracture of the femoral shaft. In both cases attention had been directed to the fracture, and the dislocation had been missed. Mr. Armstrong states that he found the management of these cases extremely difficult. In both instances the fracture of the femoral shaft was ignored, and open reduction of the dislocation was carried out. The extremities were

then immobilized in spicas in as good a position as could be secured by manipulation.

Both cases required subsequent bone-grafting of the fracture, and in each instance the entire surgical program required more than a year. In the first case an arthrodesis was performed in two stages. In the second case the initial reduction was combined with a first-stage arthrodesis, reinforced two weeks later by another procedure which included the use of a three-flanged nail. This did not result in sound fusion of the hip, and Mr. Armstrong now does not consider the combination of an open reduction with a first-stage arthrodesis a satisfactory procedure. In his opinion, open reduction of an old dislocation of the hip presents considerable difficulty, particularly in the case of a short and relatively uncontrollable proximal fragment of the femur. He feels strongly that the dislocation of the hip should be dealt with immediately and that this should take precedence over associated injuries. If the case is seen by an orthopaedic surgeon after the traction has been applied, the anteroposterior roentgenogram of the hip may be deceiving; this may be one of the causes of failure to recognize the dislocation.

CASE 13. (Courtesy of Colonel Oral B. Bolibaugh, United States Army.) This is a case of unrecognized dislocation of the hip combined with fracture of the femur observed many years ago. The initial treatment had been carried out in another hospital and the dislocation of the hip had not been recognized. The fracture of the proximal third of the femoral shaft had been plated. At the time the patient came under Colonel Bolibaugh's care he had active osteomyelitis of the femur at the site of the open reduction. Roentgenographic examination revealed persistent dislocation of the hip. After the osteomyelitis had cleared up and the shaft of the femur had united, an open reduction of the hip was carried out, under considerable difficulty. A satisfactory position was obtained, but the hip became stiff.

CASE 14. In this patient the fracture of the femur was plated overseas; the dislocation of the hip had apparently been overlooked. The dislocation was discovered at the time of the patient's arrival in the United States, and it was then found that the fracture had healed. Open reduction of the dislocation through an anterior incision was carried out in a procedure lasting four and a half hours. The patient was placed in a spica and subsequently came under the observation of one of the authors. The hip at that time was solidly ankylosed. The patient became ambulatory and later a spontaneous vertical fracture developed through the

FIG. 8-A

FIG. 8-B

FIG. 8-C

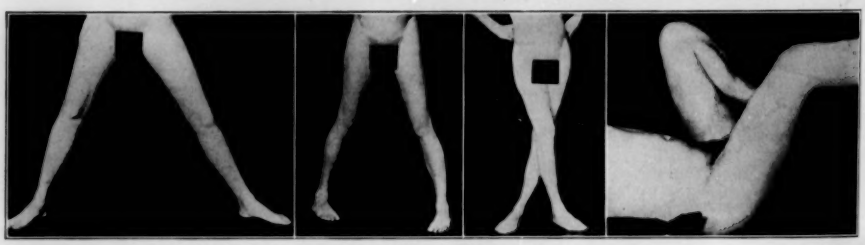

FIG. 8-D

Figs. 8-A–8-E: Case 16. The patient sustained a posterior dislocation of the right hip and a fracture of the femoral shaft on the same side, together with a fracture of the patella. There were several other severe injuries. The dislocation of the hip and the fracture of the patella were overlooked at the time of initial examination. An open reduction of the femur was performed and the fragments were secured with a wire suture. The dislocation was recognized four and a half months after injury.

Fig. 8-A: Roentgenogram made five months after injury. The medial angulation of the proximal fragment at the site of the non-union of the shaft is characteristic of an existing persistent dislocation of the hip, and even if the hip joint were not shown a dislocation should be suspected. The distal fragment of the femur points toward the acetabulum because traction has been applied.

Fig. 8-B: Lateral roentgenogram made after open reduction, seven months after the injury. The dislocation was reduced without difficulty through an anterior incision, and the fracture was reduced through an extension of the same incision. The bone graft was obtained through an oblique osteotomy in shortening the femoral shaft.

Fig. 8-C: Anteroposterior view, demonstrating an aseptic necrosis of the entire head.

Fig. 8-D: Showing shortening of the femur, and the range of motion eight months after the operation. The knee motion is limited by malunion of a fracture of the patella.

Fig. 8-E: Roentgenogram made two years and nine months after the operation. The parts of the head which have undergone revascularization show extensive structural rearrangement. Full weight-bearing was instituted at this time. (Official photograph, Photographic Section, Oliver General Hospital, Augusta, Georgia.)

neck of the femur. There was no roentgenographic evidence of aseptic necrosis of the head.

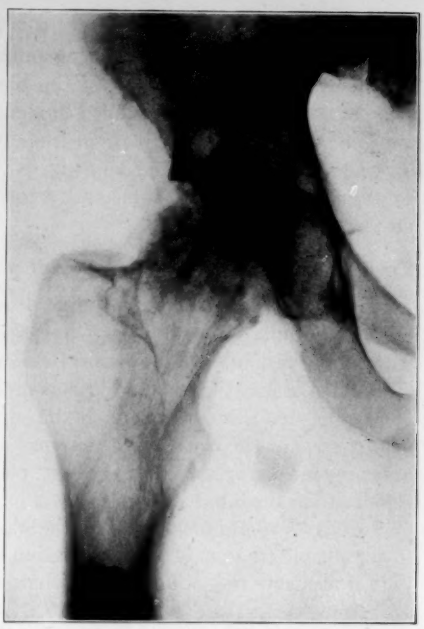

FIG. 8-E

CASE 15. The patient was hit by a falling tree and sustained a fracture in the mid-shaft of the femur, a posterior dislocation of the hip on the same side, and paralysis of the sciatic nerve.

Both the dislocation and the fracture were recognized in the initial examination. The patient was placed in skeletal traction, and the anteroposterior roentgenogram appeared to show that the hip had been reduced. Numerous roentgenograms made during the following four months were mainly concerned with the fracture, which could not be properly aligned. After this four-month period the patient was transferred to the authors' care.

Non-union of the femur and persistent dislocation of the hip were found; there was no evidence of recovery of the sciatic nerve. Open reduction was preceded by skeletal traction to secure as much muscle lengthening as possible. The hip was then approached through a posterior incision; the sciatic nerve was inspected and found to be intact. The scar tissue which filled the acetabulum could be removed easily, but reduction of the dislocation was not possible until the muscle attachments had been freed by osteotomy of both the greater and lesser trochanters. The incision was then extended distally. The fragments of the femur were aligned with difficulty because of the muscle shortening. In an attempt to prevent ankylosis of the hip such as was observed in the previous case, skeletal traction was applied, with immediate active and passive motion of the hip. At first the patient had good motion, but this decreased gradually until the hip became ankylosed. The shaft of the femur healed without further incident, while an aseptic necrosis developed in the head (Figs. 7-A and 7-B).

CASE 16. The patient was a white male, twenty-six years old, who was injured in an automobile accident. There were a posterior dislocation of the right hip, fracture of the shaft of the right femur between the proximal and middle thirds, fracture of the right patella, and many other injuries, including a severe head injury with loss of consciousness for three weeks. The fracture of the patella and the dislocation of the hip were overlooked at the time of initial examination. Alignment of the fractured femur was secured by a wire suture.

The dislocation was discovered when the patient was transferred to a military installation and came under the authors' care, four and one-half months after injury. At that time the fractured patella had united, with some deformity, the femur showed malposition and non-union, and the hip was dislocated (Fig. 8-A).

In view of our experience with previous cases, we felt that the shortening of muscles and soft tissues resulted in excessive unphysiological pressure on the hip after reduction and that this was instrumental in producing postoperative ankylosis. It was therefore decided to attempt open reduction of the hip combined with shortening of the femur to a point where it could be united without tension of the soft tissues.

The operation was carried out seven months after the injury. The hip was exposed through an anterior incision, the cicatrix was removed from the acetabulum, and the head of the femur was reduced without difficulty. The incision was then extended distally between the rectus femoris and the vastus lateralis, the wire loop was removed from the site of the non-union, and the proximal fragment was shortened by an oblique osteotomy. The fragments were then aligned without tension, and the bone was secured by a plate and transfixion screws, the fragment obtained from the osteotomy being used as a supportive bone graft (Figs. 8-B and 8-C). The patient made an uneventful recovery and retained almost full motion in the hip (Fig. 8-D). The patient was not permitted any weight-bearing for two years and nine months following reduction of the dislocation, but was ambulatory on crutches. Since revascularization of the necrotic cap of the femoral head did not seem to progress, he was then permitted full weight-bearing and unlimited activity. The hip has since remained entirely asymptomatic, and the patient has returned to military duty as a medical corpsman.

TREATMENT

Treatment is based on recognition of the dislocation. The suggestions for avoiding failure to diagnose dislocation of the hip found trivial; nevertheless, since over 50 per cent. of all known cases remained unrecognized, they are stated. A dislocation of the hip may be suspected if the proximal fragment is adducted, or if the fragments do not line up under traction as would be expected. Examination of the hip should be carried out by manual palpation as well as by roentgenogram. Both anteroposterior and lateral views are necessary.

Treatment of Fresh Dislocation of the Hip Combined with Fracture of the Femoral Shaft

In cases where there is a simple dislocation of the hip uncomplicated by fracture of the acetabulum, an attempt at closed reduction by manipulation or direct skeletal traction on the proximal fragment is often successful.

When dislocation of the hip is complicated by fracture of the acetabulum and there is no extensive fragmentation, the hip may appear reduced in the anteroposterior roentgenogram, but the acetabular fragment may be displaced anteriorly into the acetabulum and prevent reduction. In this event, open reduction through a posterior approach with repair of the acetabulum is necessary.

In cases where dislocation of the hip is combined with shattering of the acetabulum into multiple fragments, open reduction and reconstruction of the acetabulum is advised only if accurate reduction of the dislocation cannot be maintained.

Management of the Fracture of the Shaft in Fresh Injuries

In most of the cases in this series open reductions have been performed or bone grafts at a later date have been necessary, but there is no primary necessity for an operative procedure unless instability of the proximal fragment creates a special indication.

A combined operation for reduction of the dislocation and internal fixation of the shaft is a formidable procedure, and in fresh injuries may be performed in two stages.

Treatment of Unrecognized and Unreduced Dislocation of the Hip

When a persistent dislocation of the hip is combined with non-union of the fractured shaft, a major procedure for dealing with both the dislocation and the non-union at the same time may be necessary. The site of the non-union is exposed and the fragments are mobilized first, in order to permit free manipulation of the proximal fragment. If satisfactory reduction of the dislocation is obtained, the femur is shortened to the point indicated by the amount of overriding of the fragments. This prevents the abnormal tension of the shortened muscles and undue pressure on the articular cartilage of the hip.

The authors have had personal experience with both the anterior and the posterior approach in open reduction. The anterior approach is recommended as the procedure which is less difficult technically. The posterior approach was elected in one case where persistent paralysis of the sciatic nerve made exploration of the nerve desirable.

SUMMARY

Recognition of the dislocation in cases of combined dislocation of the hip and fracture of the femoral shaft is the most important factor in the prognosis and treatment of this injury.

If the dislocation is recognized prognosis for the injury is good.

The prognosis for patients in whom dislocation of the hip has remained unrecognized for a prolonged period has been poor. The authors suggest shortening of the femoral shaft as part of the treatment in such cases.

In fractures of the femur, a dislocation of the hip should be suspected if the proximal fragment is adducted or if medial angulation persists at the fracture site in spite of traction.

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TRAUMATIC DISLOCATION OF THE HIP

A Survey of Two Hundred and Four Cases Covering a Period of Twenty-one Years *

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Traumatic dislocations of the hip are so infrequent that it is difficult for any one observer to accumulate a series large enough for a proper statistical study of this important injury.

This report, based on a study of 204 dislocations, 116 of which were suitable for analysis, permits evaluation of some aspects of the injury, but the series is still too small in volume to permit evaluation of others.

MATERIAL

There were 204 patients with dislocation of the hip treated in the Los Angeles County Hospital during the twenty-one-year period from July 1928 to July 1949. One hundred

TABLE I

Distribution of 204 Cases of Dislocation of the Hip by Type, Sex, and Age Groups

Type of Dislocation	No. of Cases	Per Cent.
Anterior	18	9
Posterior	186	91
Total	204	100

Sex	No. of Cases	Per Cent.
Male	153	75
Female	51	25
Total	204	100

Age (*Years*)	No. of Cases	Per Cent. of Series
0 to 15	17	8
16 to 30	85	42
31 to 40	46	23
41 to 50	30	14
51 to 60	16	8
61 to 80	10	5
	204	100

and thirty additional cases of central fracture or central fracture-dislocation seen during this same period are not included in this survey, but will be reviewed separately. During the first ten and a half years of the survey, there were seventy-two cases. During the second half of the survey there were 132 cases, an increase of 70 per cent. Of the 204 cases there was one anterior dislocation to every ten posterior dislocations (Table I); one fourth of all dislocations occurred in females; and nearly two thirds of the patients were between the ages of sixteen and forty years. Five deaths occurred within one to five days because of severe multiple injuries.

These dislocations were treated on a large fracture service by many orthopaedic

* Based on a preliminary report given to the Western Orthopedic Association, Santa Barbara, California, October 21, 1949.

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surgeons trained at various medical centers. The supervision probably represented a cross section of experience and opinion of the period covered by the twenty-one-year survey. The prompt recognition of the dislocation and treatment of most of the patients, considering the high incidence of serious associated injuries, must be credited to the resident staff.

The chief fault in the material is the lack of repeated observations, especially in those cases with a longer follow-up period. Standards for the selection of cases and for methods of evaluation were, therefore, carefully considered in order to make up for this defect as far as possible.

Eighty-eight of the 204 patients were excluded from this study for either one of two reasons. First, because the result could not be properly ascertained. For instance, no case not physically or roentgenographically examined was included on negative evidence alone. (Nine patients re-admitted to the Hospital for other conditions were not included because there was no mention of the hip in the new history, no note in the physical examination, and no follow-up roentgenogram of the hip. Two former patients, treated as children, reported by telephone, ten and thirteen years after injury respectively, that they had no symptoms, but there was no other confirmation and they were not included in the series.) Second, cases with a good result were discarded if they had been followed for less than one year. However, since only one case had an initially fair result which later improved enough to be classified as good, it was decided to include all cases having a fair or poor result, even if the period of follow-up was less than one year.*

Exclusion of these eighty-eight dislocations leaves a series of 116 cases considered suitable for analysis.

For this purpose sixty-eight cases were examined clinically by one or both of the authors; thirty-six were examined by other orthopaedic surgeons; ten by physicians or personal communication; and two were not examined clinically. Of these, 106 were examined by roentgenographic review by both authors. No end-result roentgenograms were available in ten cases.

The minimum follow-up period was three months, the maximum, nineteen years and four months. There were seventy-eight cases followed for less than five years and thirty-eight cases followed for more than five years. The average period of follow-up was three years and nine months.

CLASSIFICATION OF INJURY

Dislocations were divided into anterior and posterior groups. The posterior dislocations were divided into five types:

Type I. With or Without Minor Fracture.
Type II. With Large Single Fracture of Posterior Acetabular Rim.
Type III. With Comminuted Fracture of Rim of Acetabulum, With or Without Major Fragment.
Type IV. With Fracture of Acetabular Rim and Floor.
Type V. With Fracture of Femoral Head.

The separation of posterior dislocations with fracture of a large single fragment of the posterior acetabular rim from the dislocations with comminuted fractures of the posterior rim will be shown to be justified by the choice of treatment used and by the difference in outcome.

Armstrong used an anatomical classification of four main types: dislocation only, dislocation with fracture of the acetabular rim, dislocation with fracture of the acetabular floor, and dislocation with fracture of the femoral head. The fractures of the acetabular floor included central dislocations in the cases reported. The authors' classification divides into two types the dislocations with acetabular-rim fracture and excludes central fractures

* Of the total of seventy-eight cases with fair or poor results, twenty-six had a follow-up period of less than one year.

TABLE II

ROENTGENOGRAPHIC CRITERIA FOR EVALUATING RESULTS

Excellent (Normal) All of the Following:	*Good* (Minimal Changes)
1. Normal Relationship between Head and Acetabulum.	1. Normal Relationship between Head and Acetabulum.
2. Normal Articular Cartilaginous Space.	2. Minimal Narrowing of Cartilaginous Space.
3. Normal Density, Head of Femur.	3. Minimal De-ossification.
4. No Spur Formation.	4. Minimal Spur Formation.
5. No Calcification in Capsule.	5. Minimal Capsular Calcification.
Fair (Moderate Changes)	*Poor* (Severe Changes)
1. Normal Relationship between Head and Acetabulum.	1. Almost Complete Obliteration of Cartilaginous Space.
Any One or More of the Following:	2. Relative Increase in Density of Femoral Head.
2. Moderate Narrowing of Cartilaginous Space.	3. Subchondral Cyst Formation.
3. Mottling of Head, Areas of Sclerosis, and Decreased Density.	4. Formation of Sequestrae.
4. Moderate Spur Formation.	5. Gross Deformity of Femoral Head.
5. Moderate to Severe Capsular Calcification.	6. Severe Spur Formation.
6. Depression of Subchondral Cortex of the Femoral Head.	7. Acetabular Sclerosis.

without posterior dislocation. After reduction, many cases of our Type IV have the appearance of central fractures with medial displacement of the head. The variety of positions of the head and the extent and comminution of the accompanying fractures occasionally make precise classification difficult. However, for purposes of this study, the classification given has been satisfactory. Several subdivisions made early in the survey later proved not to be useful.

Campbell divided posterior dislocations with posterior rim fractures into three types, based on the extent of displacement of the head as shown in the roentgenogram. He also stressed the fact that a slight displacement of the head may easily be missed. This is confirmed by several cases in this series which were unrecognized until lateral roentgenograms were made. Since it is usually impossible to know the extent of the excursion of the head at the moment of dislocation or to determine the amount of movement toward reduction at the time the roentgenogram is made, we have classified these cases on the basis of the type of bone and joint injury.

CLASSIFICATION OF RESULTS

The results were judged independently by roentgenographic and clinical methods. If the two methods disagreed as to result, the case was assigned to the lower of the two grades.

The roentgenographic rating was based on the following observations (Table II):

1. Position: Reduced. Not Reduced.
2. Cartilaginous Joint Space: Normal. Diminished (Mild, Moderate, Severe).
3. Variations in Bone Density of Head: Mottling, Cystic Formation, or Sequestra.
4. Subchondral Irregularities of Head.
5. Acetabular Sclerosis.
6. Capsular Calcification: Mild, Moderate, Severe.
7. Spur Formation: Mild, Moderate, Severe.

Results were considered to be excellent when there was no change due to trauma (Figs. 1-A to 2-B and 4-A to 4-C); good when there were minimal changes (Figs. 5-A and

TABLE III

CLINICAL CRITERIA FOR EVALUATING RESULTS

Excellent: All of the Following	*Good:*
1. No Pain.	1. No Pain.
2. Full Range of Hip Motion.	2. Free Motion (75 per cent. of Normal Hip).
3. No Limp.	3. No More than a Slight Limp.
X. No Roentgenographic Evidence of Progressive Changes.	*X*. Minimal Roentgenographic Changes.
Fair: Any One or More of the Following	*Poor:* Any One or More of the Following
1. Pain, but Not Disabling.	1. Disabling Pain.
2. Limited Motion of Hip. No Adduction Deformity.	2. Marked Limitation of Motion or Adduction Deformity.
3. Moderate Limp.	3. Redislocation.
X. Moderately Severe Roentgenographic Changes.	*X*. Progressive Roentgenographic Changes.

(*X* = Roentgenographic criteria summarized)

5-B, 10-A and 10-B, 11-A to 11-D); fair when changes were moderate (Figs. 8-A and 8-B); and poor when changes were severe (Figs. 9-A to 9-C, 12-A to 12-C, 13-A to 13-D).

The clinical criteria for the evaluation of results are summarized in Table III. With respect to subjective findings, patients who had *no pain* were considered to have excellent or good results. A patient with a good result, however, might have a sense of stiffness after long sitting. Patients were considered to have a fair result if they had some pain but not to an incapacitating degree, even if they had to change to a less arduous occupation than before. In those patients with poor results the pain was considered disabling even if the patient was only partially incapacitated. Thus a housewife able to do her cleaning and cooking adequately, but requiring frequent rest or a crutch, was considered to have a poor result.

Objectively, those hips with normal physical findings were classified as excellent, while those with some restriction of motion, but without muscle spasm or deformity, were classified as good. Some patients with a good result had a slight limp after fast walking or gave a history of limp upon fatigue. Patients with significant limitation of motion but no adduction deformity were considered to have a fair result; in these patients muscle spasm usually could be elicited by forcing motions at their extremes; a limp was usually present. The findings in the poor results were muscle spasm with severe restriction of motion, adduction deformity, and limp.

Comparison of Roentgenographic Grading and Clinical Grading

A comparison of results of the roentgenographic grading and the clinical grading is shown in Table IV. This table is made by cross-charting the results under both the clinical grades (read vertically) and the roentgenographic grades (read horizontally) in the 104 cases suitable for the method. The twelve cases with an unknown result by one or the other method are shown, to account for the total of 116 cases.

Of the 104 cases in which results were evaluated by both methods, there was complete agreement in eighty. In the twenty-four cases where the two methods of grading produced different results, the difference was by one grade only in twenty-two cases and by two grades in two. It is interesting that in sixteen of these the clinical evaluation was less favorable than the roentgenographic findings.

As it was believed that there were certain to be a few overlapping cases, the lower grade by either method was chosen to provide the proper rating for the case in which roentgenographic change lagged behind symptoms, or in which the pathological changes

FIG. 1-A FIG. 1-B FIG. 1-C

R. B. 751-299. Six years old. This was an anterior dislocation without fracture, with an excellent result.

Fig. 1-A: The patient slipped and fell February 8, 1941. The dislocation was reduced on the same day and a spica cast was applied. The patient walked in three weeks.

Fig. 1-B: Roentgenogram made two months later.

Fig. 1-C: Follow-up roentgenogram made August 1, 1949. There was a normal range of hip motion and the patient had no complaints.

FIG. 2-A

FIG. 2-B

R. E. 845–481. Twenty-eight years old. The roentgenograms show another example of an anterior dislocation without fracture; the result was excellent.

Fig. 2-A: The patient was struck by an automobile November 15, 1947. Besides the dislocation there was a compound fracture in the contralateral extremity. Reduction was performed on the same day. Traction was applied for three months and the patient walked after four months.

Fig. 2-B: Follow-up roentgenogram two years later. The range of hip motion was normal and the patient had no complaints.

Fig. 3: T. O. 435–770. The roentgenogram shows an anterior dislocation with fracture of the ilium. Because there was no follow-up examination, this case was used only to illustrate this type of fracture.

FIG. 3

revealed by roentgenograms were not fully symptomatic.

Results in the 116 Dislocations Classified according to Type
(Table V)

Anterior Dislocations

Only five of the eighteen patients with anterior dislocations could be traced. They all had excellent results. The number is too small to be significant, and poor results are known to occur sometimes, but the outcome appears to be favorable as far as this group is concerned.

Posterior Dislocations (111 cases)

Type I posterior dislocations numbered thirty cases. There were ten each of excellent and good results and five each of fair and poor results.

FIG. 4-A FIG. 4-B FIG. 4-C

R. M. 498-975. Sixteen years old. The patient sustained a posterior dislocation, Type I, in a collision between an auto and a freight train. The result was excellent.

Fig. 4-A: Roentgenogram made on day of injury, May 29, 1936.

Fig. 4-B: Roentgenogram made on the same date, after reduction. The period of bed rest was three weeks, and the patient walked after seven weeks.

Fig. 4-C: Roentgenogram made at follow-up examination, thirteen years and one month later. There is an ununited fragment at the site of the attachment of the ligamentum teres. The range of hip motion was normal and the patient had no complaints.

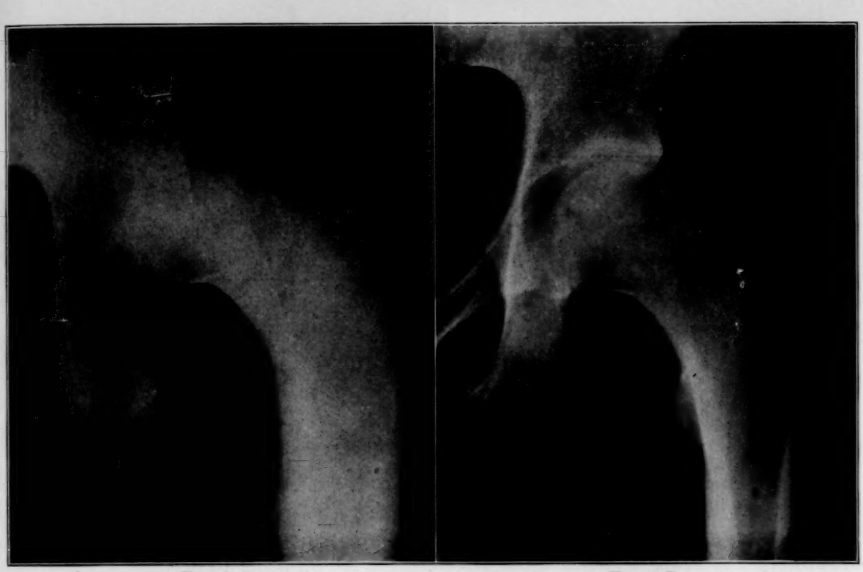

FIG. 5-A

FIG. 5-B

G. J. 801–858. Twenty years old. The patient sustained a posterior dislocation, Type I. The result was good.

Fig. 5-A: Roentgenogram made on the day of injury, April 12, 1942. The patient was in an auto which crashed into a train. The dislocation was reduced on the same day. Traction was applied for ten days and the patient walked after six weeks.

Fig. 5-B: Roentgenogram made seven years and four months later. There is minimal spur formation at the superior margin of the head and neck. The patient had no pain but felt discomfort after sitting, and there was slight limitation of hip motion.

Fig. 6: H. C. 658–147, twenty-one years old. The roentgenogram shows a posterior dislocation, Type I, which later had a fair result. The patient was injured in an auto collision on March 10, 1939, and entered the hospital twelve days after the injury. Three attempts at reduction were made within three days. The period of follow-up was five months. There was extensive myositis ossificans. This was one of two such cases in the series.

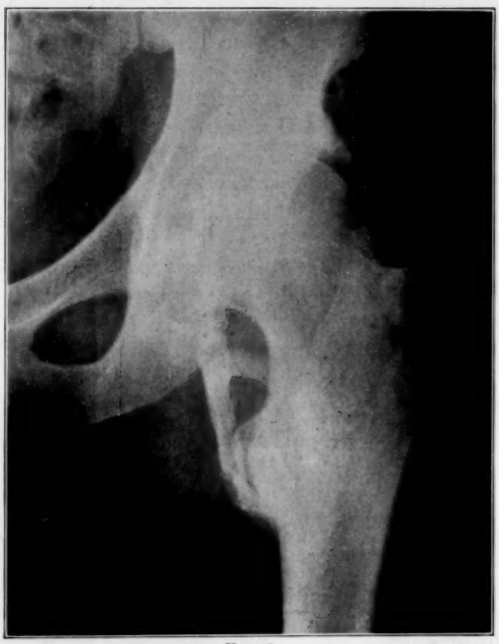

FIG. 6

Type II included twenty-two cases. The results were distributed as excellent, none; good, seven; fair, six; poor, nine. Comparison of the results in Types I and II suggests a difference in expected outcome.

Types III, IV, and V, like Type II, showed no excellent results A great proportion of these cases had either fair or poor results. In Type III, sixteen of twenty-eight cases had poor results. Type IV showed fifteen out of twenty cases rated as poor. Type V, with only eleven cases, showed one good result and five each in the fair and poor grades.

It was thought that the apparent differences in outcome in Types I and II compared

TABLE IV

ROENTGENOGRAPHIC GRADING COMPARED WITH CLINICAL GRADING

Roentgenographic Grade	Clinical Grade: Excellent	Good	Fair	Poor	Unknown	Total
Excellent	15	13	2	0	0	30
Good	0	5	1	0	2	8
Fair	0	8	14	0	0	22
Poor	0	0	0	46	0	46
Unknown	0	3	3	4	0	10
Total	15	29	20	50	2	116

Clinical grades read downward; roentgenographic grades read across.

In 12 cases clinical or roentgenographic results are unknown. Clinical and roentgenographic results agree in 80 cases (broken line). Clinical and roentgenographic results disagree by 1 grade in 22 cases (single closed line). Clinical and roentgenographic results disagree by 2 grades in 2 cases (double closed line).

When Excellent and Good and Fair and Poor are combined, there are only 2 disagreements and 12 in which results are unknown.

to results in Types III, IV, and V might be significant. In order to obtain adequate numbers in each type and grade, the cases with excellent and good results were combined into one group and those with fair and poor results into a second group. There being no significant difference between Types III, IV, and V, these types were combined to form a third group (Table VI).

Type I, thirty cases, presented twenty excellent or good and ten fair or poor results. Of twenty-two Type II cases, only seven were excellent or good and fifteen were rated fair or poor. Of fifty-nine cases in Types III, IV, and V, fifty-three were rated fair or poor; only six cases were rated as excellent or good. These differences are considerable, quite aside from the fact that in Types II, III, IV, and V there were no excellent results (Table V).

The number of cases in the several categories listed in Table V were considered sufficient for statistical analysis. The differences were found to be significant * between Types I and II, and between Types II and III, IV, and V combined. (Type I as compared with Type II, $p = 0.01$; Type II as compared with Types III, IV, V, $p = 0.05$.)

Armstrong reported early results, obtained largely through questionnaires and many roentgenograms, in a series of 100 cases with complete recovery in 76 per cent. of simple

* Unless otherwise qualified, the term "significant" indicates a probability of .05 or less.

TABLE V

RESULTS IN 116 DISLOCATIONS EVALUATED BY TYPE

Type	Excellent	Good	Fair	Poor	Total
Anterior	5	0	0	0	5
Posterior					
Type I	10	10	5	5	30
Type II	0	7	6	9	22
Type III	0	4	8	16	28
Type IV	0	1	4	15	20
Type V	0	1	5	5	11
Total	15	23	28	50	116

TABLE VI

RESULTS IN POSTERIOR DISLOCATIONS

	Excellent or Good No. of Cases	Fair or Poor No. of Cases	Total
Type I	20	10	30
Type II	7	15	22
Types III, IV, and V	6	53	59
Total	33	78	111

dislocations and in 63 per cent. of cases with acetabular-rim fractures, in 40 per cent. of dislocations with fracture of the femoral head, and in none of the cases with fractures of the acetabular floor.

Results in 116 Dislocations (Cases followed for less than five years compared with cases followed for more than five years.)

The seventy-eight cases of dislocation with a follow-up period of less than five years are compared with the thirty-eight cases of dislocation followed for more than five years in terms of excellent and good and fair and poor results combined (Table VII).

The number of cases is not enough to make significant comparisons by type. However, when the results in the cases followed for over five years, the cases followed for less than

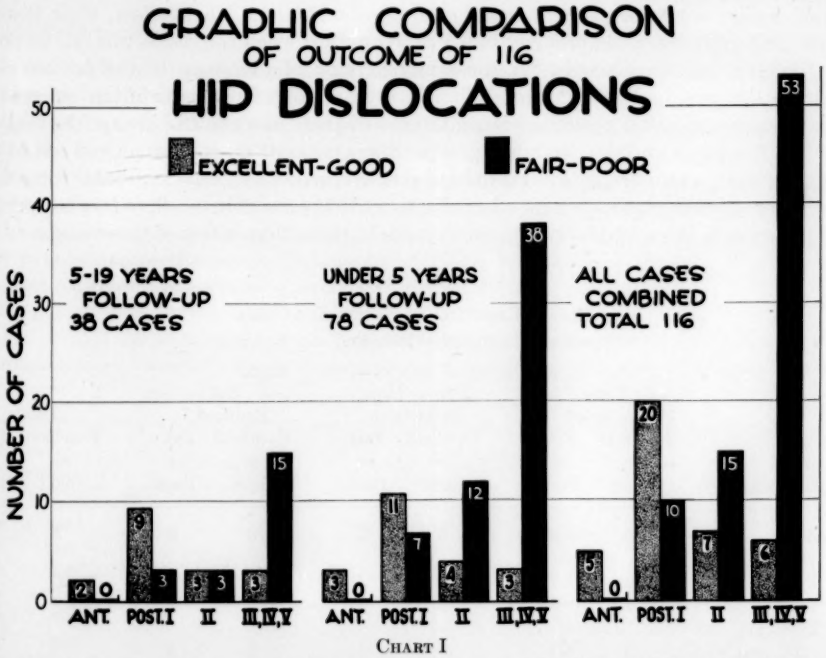

CHART I

The chart presents the excellent or good and fair or poor results of the 116 dislocations divided into three groups. To the left are shown the thirty-eight cases followed for five to nineteen years. The middle group consists of the seventy-eight cases followed for less than five years. The results in the two groups combined are seen at the right. Numbers in the first group are too small to permit significant comparison by type. The chart shows the similarity of distribution of results by type in the three groups described.

TABLE VII

RESULTS IN 116 DISLOCATIONS

Type	Seventy-eight Dislocations Followed for Less than Five Years: Excellent or Good	Fair or Poor	Total	Thirty-eight Dislocations Followed for More than Five Years: Excellent or Good	Fair or Poor	Total
Anterior	3	0	3	2	0	2
Posterior						
Type I	11	7	18	9	3	12
Type II	4	12	16	3	3	6
Types III, IV, and V	3	38	41	3	15	18
Total	21	57	78	17	21	38

five years, and the whole group of 116 cases are graphed by type, a similarity of distribution is observed (Chart I). There is no evidence in this series that a case graded within the first five years according to roentgenographic and physical findings and symptoms will be assigned to a higher or lower grade at a later date. Only one case in this series was changed from a clinical grading of fair to good; this change was made three years after the dislocation, when the patient's pain disappeared (the roentgenographic rating had always been good). However, it must be emphasized that the majority of the patients treated earlier went for years without interval observation. Nonetheless, their history almost uniformly consisted of a continuity of symptoms when the result was fair or poor.

Explanations were sought for the apparent lack of follow-up in the fair or poor results in the group followed for more than five years. The acceptance of fair or poor results whenever so rated placed a preponderance of these cases in the group followed for less than five years and the combined groups. Some patients must have moved out of the county or died; a number are known to have refused further surgical treatment; some may have become discouraged when no other effective treatment could be offered. It is doubtful that end results improved by one or two grades in more than a few of these cases.

TABLE VIII

CLOSED REDUCTIONS—NINETY-ONE CASES

Number of Reductions Compared with Outcome

Closed Reductions	One Reduction: Excellent or Good	Fair or Poor	Two or More Reductions: Excellent or Good	Fair or Poor	Not Reduced *: Excellent or Good	Fair or Poor	Totals: Excellent or Good	Fair or Poor
Anterior	5	0	0	0	0	0	5	0
Posterior								
Type I	20	7	0	2	0	1	20	10
Type II	7	5	0	0	0	4	7	9
Types III, IV, and V	3	21	0	8	0	8	3	37
Totals	35	33	0	10	0	13	35	56

* Not reduced because: unrecognized, 4; no attempt made at closed reduction, 4; irreducible, 2; unstable, 3.

TABLE IX

CLOSED REDUCTIONS—NINETY-ONE CASES

Number of Hours before Reduction Compared with Outcome

No. of Hours	0 to 24		25 to 48		49 or More		Not Reduced *		Total	
Type	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor
Anterior	5	0	0	0	0	0	0	0	5	0
Posterior										
Type I	19	6	1	1	0	2	0	1	20	10
Type II	7	3	0	1	0	1	0	4	7	9
Types III, IV, and V	3	26	0	2	0	1	0	8	3	37
Total	34	35	1	4	0	4	0	13	35	56

* For the following reasons: unsuccessful attempts, 2 cases; unrecognized, 4 cases; not attempted, 4 cases; unstable, redislocated, 3 cases.

The ideal of a long-term follow-up study is not approached even in the group followed for more than five years. The total number of thirty-eight cases dwindles rapidly when subdivided into the different types of injuries and results so that these have only tentative significance. Unknown factors which will influence the selection, interposed over a period of time, can only be eliminated by repeated observation of a sufficient number of patients.

Closed Reductions: Number of Attempts at Reduction Compared with Outcome

The results of ninety-one closed reductions are tabulated as excellent or good and fair or poor under the number of attempts at reduction (Table VIII). All of the five anterior and sixty-three of the eighty-six posterior dislocations were reduced at the first attempt. All of the excellent and good results were in this group. All of the dislocations with two or more attempts at reduction had fair or poor results. To the ten cases reduced after two or more attempts should be added four more cases either irreducible or unstable. Most of these fourteen cases were of the unfavorable Types III, IV, and V. It should be noted that twenty-one of the twenty-four cases of Types III, IV, and V reduced at the first attempt had only fair or poor results.

TABLE X

RESULTS IN 111 POSTERIOR DISLOCATIONS

Twenty-five Open Reductions and Eighty-six Closed Reductions

Method of Reduction	Excellent	Good	Fair	Poor	Total
Type I Closed	10	10	5	5	30
Type II Open	0	0	4	2	6
Type II Closed	0	7	2	7	16
Type III Open	0	3	2	7	12
Type III Closed	0	1	6	9	16
Type IV Open	0	0	0	5	5
Type IV Closed	0	1	4	10	15
Type V Open	0	0	0	2	2
Type V Closed	0	1	5	3	9
Total	10	23	28	50	111

FIG. 7-A

FIG. 7-B

FIG. 7-C

E. C. 500–712. Fifty-two years old. This case belongs to the group of posterior dislocations, Type II. The injury was sustained in a collision between an auto and a truck. A closed reduction was performed and the result was good.

Fig. 7-A: Roentgenogram made on the day of injury, August 20, 1949. There was peroneal palsy, with a return of normal function after four months. Reduction was performed on the same day and traction was applied and maintained for ten weeks. The patient walked after sixteen weeks.

Fig. 7-B: Roentgenogram made after reduction. Note that the acetabular fragment has not been restored to its anatomical position.

Fig. 7-C: Roentgenogram made at follow-up examination nine years and one month later, showing superior rounded lipping of the acetabulum and minimal narrowing of the cartilaginous space. The patient had no pain but felt discomfort after sitting, and there was slight limitation of hip motion.

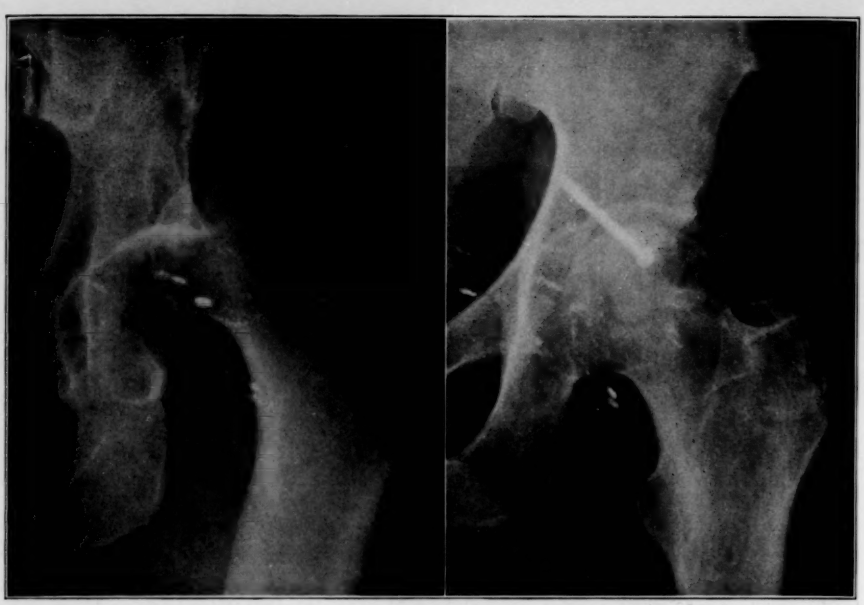

FIG. 8-A FIG. 8-B

T. Mc. 1148–368. Thirty-four years old. The roentgenograms show a posterior dislocation, Type II. An open reduction was performed, with a fair result.

Fig. 8-A: Roentgenogram made May 29, 1949. The injury was due to an auto collision. The patient also suffered thoracic injuries. A closed reduction was performed on the same day. An open reduction, using the posterior approach with replacement of the fractured acetabular fragment, was performed on the twelfth day.

Fig. 8-B: Follow-up roentgenogram taken six months later. There was relative increased density of the central weight-bearing portion of the head, with a subchondral depression at its juncture to the atrophic lateral portion of the head. The cartilaginous joint space was still maintained. The patient had pain, muscle spasm, and moderate limitation of hip motion.

The number of cases with two or more reductions is too small to permit comparison.

Clinically, there seems no need for comparison to indicate that one reduction is better than adding trauma upon trauma. The increasing difficulty in securing reduction at the first attempt in Types III, IV, and V, compared to the high incidence of success in the group with anterior dislocation and in Types I and II, suggests that these types may require a different approach.

Mention may be made of the methods of closed reduction used in this series. They were: Allis' method, forty-two cases; unknown, twenty-four cases; Stimson's, seven cases; Bigelow's, three cases; reduction while traction was being applied, one case; spontaneous reduction while turning a patient after spinal anaesthesia, one case; unreduced, thirteen cases; total, ninety-one cases. The excellent Stimson method is not useful in some cases with associated injuries. The general principles of reduction are traction in the line of deformity, restoration of alignment, and apposition in the absence of muscle spasm.

Closed Reductions: Length of Time before Reduction in Relation to the Outcome

The result in ninety-one cases is evaluated in terms of the time elapsed before closed reduction (Table IX). All of the five anterior and sixty-four of the posterior dislocations were reduced within the first twenty-four hours. The thirteen cases of dislocation not reduced include two unsuccessful cases, two with unstable hips, four in which the dislocation was not recognized, and four in which reduction was not attempted because of the patients' general condition.

FIG. 9-A FIG. 9-B FIG. 9-C

J. S. 957–938. Thirty-five years old. The roentgenograms show a posterior dislocation, Type II, on which an open reduction was performed. Avascular necrosis developed and the result was poor.

Fig. 9-A: The patient was injured February 8, 1946, in a collision of an auto and a truck. A closed reduction was performed the same day.

Fig. 9-B: Roentgenogram made after the closed reduction. An open reduction was performed seven days later.

Fig. 9-C: Follow-up roentgenogram after three years and seven months. Patient had disabling pain, muscle spasm, and severe limitation of hip motion. Note the central depression in the dense fragment of the femoral head, and the mottled cancellous bone of head, with bone production at the margins of the head and neck; superiorly there is still a fair but irregular cartilaginous space, but medially it is thin.

FIG. 10-A FIG. 10-B

T. A. 870-383. Twenty-one years old. This was a posterior dislocation, Type III, on which an open reduction was performed. The result was good.

Fig. 10-A: The patient was injured February 19, 1944, in an auto accident. No attempt at closed reduction was made. An open reduction, with removal of three fragments of bone from the hip joint, was made on the fifth day.

Fig. 10-B: Roentgenogram made five years and ten months after injury. The patient had no pain but there was slight limitation of hip motion. Very slight irregularity of the subchondral cortex of the head was noted.

Again, the number of cases in which reductions were attempted after the twenty-four-hour period is too small and scattered to permit comparison. Only one excellent or good result was seen in reductions performed on the second day; results in the others were all fair or poor. This experience is similar to that of Funsten and his associates, who reported good results in early reductions of uncomplicated dislocations.

Delay in reduction was caused by lack of recognition, poor condition of the patient, and lack of success in the initial attempt at reduction. Increasing watchfulness, especially of the patient with other more obvious injuries, is necessary to avoid missing dislocations. Lateral or oblique views should be made routinely, as well as roentgenograms of the pelvis. The few cases in which the dislocation could not be reduced because of the condition of the patient emphasize the value of prompt treatment of shock and the use of adequate traction when anaesthesia is contra-indicated.

The lack of success in early attempts at reduction again suggests that open reduction may be necessary in such cases.

Results in Posterior Dislocations: Open and Closed Reductions Compared

The 111 posterior dislocations were reduced by closed methods in eighty-six cases and by open operation in twenty-five. The distribution by type is shown in Table X.

Type I. In all of these cases, reductions were by closed methods except in one which was irreducible. A case of King and Richards' shows that an apparently minor avulsion fracture with a fragment attached to the capsule or ligamentum teres may interfere with

FIG. 11-A FIG. 11-B

reduction. Appreciation of this possibility may salvage an occasional Type I dislocation not readily reduced by the closed method.

Type II. Of twenty-two cases the only good results were in seven patients who had closed reductions. The other nine cases with closed reductions had fair or poor results. The results in all six open reductions were fair or poor. The numbers are too small to be statistically compared.

Before an attempt is made to evaluate these results, the findings in the individual cases summarized below should be considered.

TABLE XI

POSTERIOR DISLOCATIONS

Interval before Open Reduction in Twenty-five Cases *

No. of Days between Dislocation and Reduction	Type II		Type III		Type IV		Type V		
	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Total
0 to 6	0	1	3	3	0	1	0	1	9
7 to 13	0	3	0	2	0	2	0	0	7
14 to 20	0	1	0	1	0	0	0	0	2
21 to 27	0	0	0	0	0	1	0	1	2
28 to 34	0	0	0	1	0	0	0	0	1
35 to 41	0	0	0	1	0	0	0	0	1
42 to 49	0	0	0	0	0	0	0	0	0
50 and Over	0	1	0	1	0	1	0	0	3
Total	0	6	3	9	0	5	0	2	25

* Of 25 open reductions, 5 had no previous attempts at closed reduction, 15 had one attempt, 3 had 2 attempts, and 2 had 3 attempts.

FIG. 11-C FIG. 11-D

L. H. 535–618. Seventeen years old. The roentgenograms show a posterior dislocation, Type IV. A closed reduction was performed and the result was good.

Fig. 11-A: The patient was injured January 17, 1937, in a collision of two trucks. The reduction was made on the same day.

Fig. 11-B: Roentgenogram made after reduction. Note the fracture through the triradiate cartilage and the large fracture of the posterior acetabular rim.

Fig. 11-C: Roentgenogram made nearly four years later. The patient had some stiffness but no pain, although pain had persisted for three years. Full weight-bearing had been resumed three months after the injury.

Fig. 11-D: Roentgenogram made twelve years and nine months later. There was no pain, but the patient had some discomfort after dancing or hard work. Note the change in the trabecular pattern of the head and the slight irregularity of the subchondral cortex.

Closed Reductions

Cases with good results: In all seven cases the dislocations were reduced within the first twenty-four hours; the average time before weight-bearing was four months.

TABLE XII

HIP SURGERY OTHER THAN OPEN REDUCTION IN EIGHT CASES: INTERVAL AFTER INJURY AND RESULT

Procedure	Type of Dislocation	Time Elapsed between Dislocation and Operation (*Months*)	End Results
Arthroplasty (cup)	III	12	Poor
Arthroplasty (fascial)	III	12	Poor
Arthroplasty (cup)	III	36	Poor
Arthrodesis	IV	4	Good
Arthrodesis	IV	3	Good
Arthrodesis	IV	714	Good
Arthrodesis	V	1	Good
Reconstruction	V	3.5	Poor

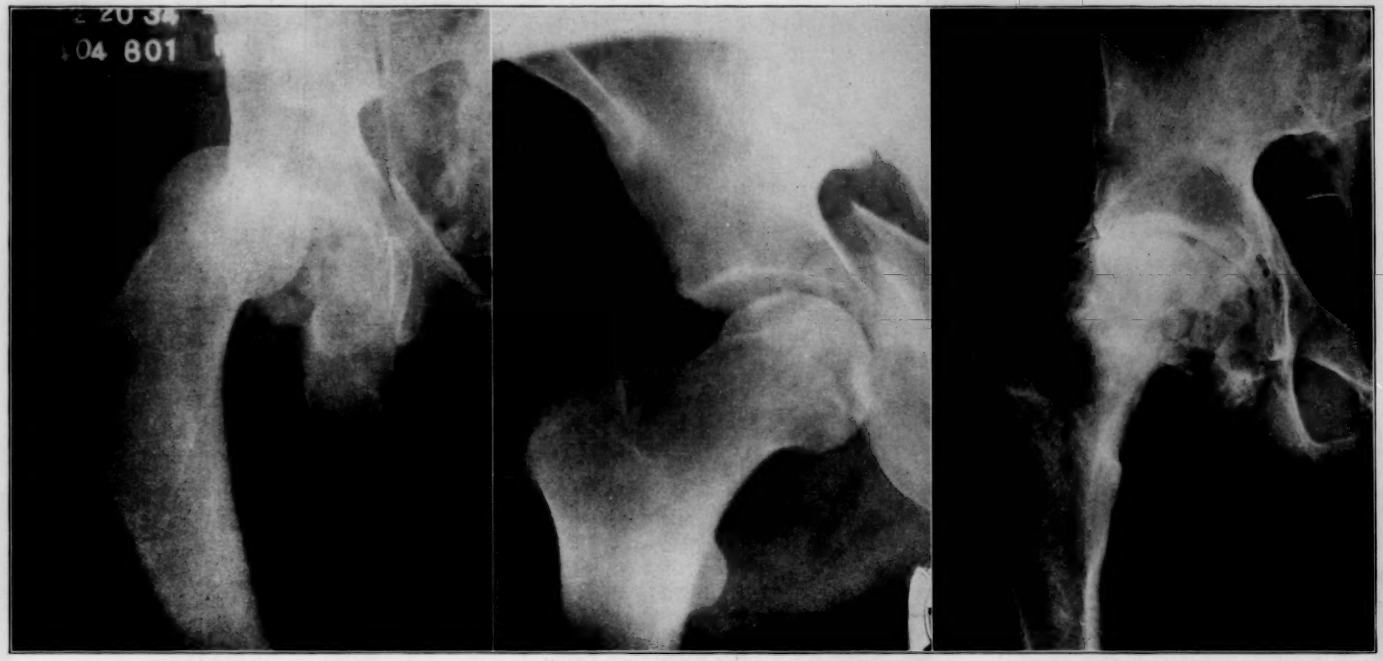

FIG. 12-A FIG. 12-B FIG. 12-C

P. B. 404–801. Sixty years old. This was a posterior dislocation, Type IV, on which a closed reduction was performed. Avascular necrosis developed and the result was poor.

Fig. 12-A: The patient was injured December 20, 1934, in a collision between an auto and a streetcar. There was a compound fracture of the ipsilateral tibia. Reduction was performed on the same day.

Fig. 12-B: Roentgenogram made eleven days after reduction. Note resemblance to a central protrusion-fracture of the acetabulum. Traction was applied for four months and the patient walked after six months.

Fig. 12-C: Roentgenogram made after eleven years and three months. The patient has had persistent pain in the hip and knee since weight-bearing was begun. Note advanced avascular necrosis, with sequestra of the head, narrow cartilaginous space, and bone production.

FIG. 13-A

FIG. 13-B

FIG. 13-C

FIG. 13-D

A. F. 1097–924. Twenty-two years old. This was a posterior dislocation, Type V, on which an open reduction was performed. Avascular necrosis developed and the result was poor.

Fig. 13-A: The patient was injured August 7, 1948, in an auto collision. There was also a fracture in the proximal third of the ipsilateral tibia, with circulatory impairment. Note the free fragment of the head of the femur. The dislocation was irreducible by closed manipulation; an open reduction was performed three weeks after injury.

Fig. 13-B: Roentgenogram made about three months after open reduction. The acetabular labrum was folded over the acetabulum and prevented closed reduction. The fragment from the fractured head

(*Continued on page 766*)

(*Continued from page 765*)

was not removed. There was sufficient atrophy of the proximal portion of the femur to show the unchanged density of the head.

Fig. 13-C: Roentgenogram made five months after reduction. Note the general atrophy, especially of the upper end of the femur, except for the lunate area of increased density at the weight-bearing portion of the head. Capsular calcification is evident.

Fig. 13-D: Roentgenogram made one year later. Note the increased capsular calcification and the spreading of irregular areas of increased density at the weight-bearing portion of the head. The cartilaginous joint space is narrowed. The patient had pain and limitation of hip motion.

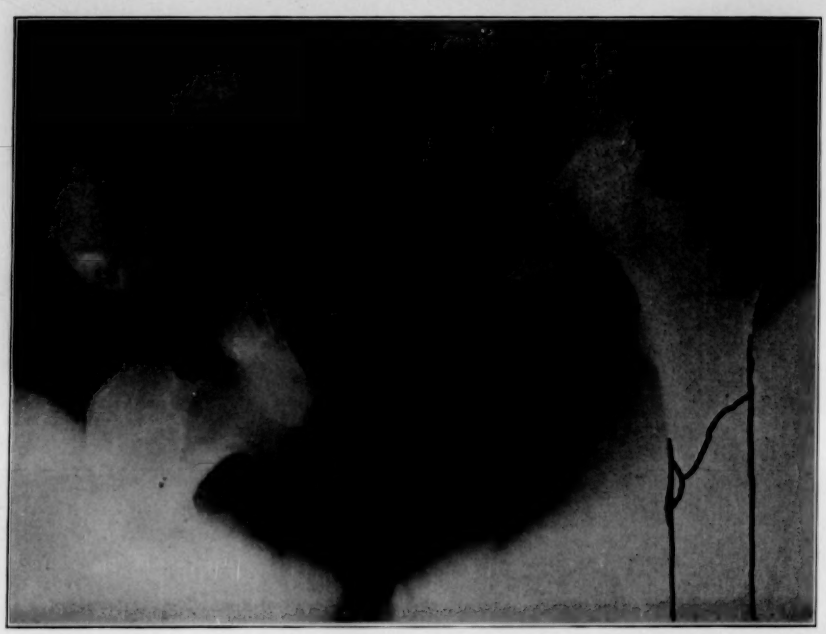

FIG. 14

R. S. 716–045. Twenty-three years old. The patient sustained an anterior dislocation on the right side, and a posterior dislocation, Type IV, on the left, together with a fracture of the shaft of the femur and peroneal palsy. The approximate location of the fracture in the diaphysis is indicated by the lines drawn on the roentgenogram.

The patient was injured May 12, 1940, in an auto collision. The posterior dislocation on the side of the femoral-shaft fracture was not recognized.

Note the fracture of the inner table of the acetabulum at the juncture of the left ischium and ilium. The head of the femur is not in anatomical relationship with the acetabulum. There are comminuted rim fractures.

The result after five years and ten months was found to be excellent for the anterior dislocation. It was poor for the posterior dislocation, and there was traumatic arthritis.

Cases with fair results: In one case the dislocation was reduced in seventy-two hours and in one two hours after injury, with weight-bearing in two and a half months in both cases.

Cases with poor results: In two cases the dislocations were reduced within eight hours, with weight-bearing allowed at the fifth and eighth week respectively. In one case the dislocation was reduced after forty-eight hours; the patient walked in six months. In four patients the dislocations were not reduced for the following reasons: In one the dislocation was not recognized, one had a nine-day-old dislocation with a fracture of the ipsilateral femoral shaft, one had a month-old dislocation for which traction proved unsuccessful, and in the last the general condition was poor and no attempt at reduction was made.

Open Reductions

Cases with fair results: One reduction was unstable. There were three cases in which previous attempts at closed reductions had been made. Three patients were operated upon twelve, fifteen and sixty days after dislocation respectively.

TABLE XIII

AGE DISTRIBUTION ACCORDING TO TYPE AND RESULT *

Age Group (*Years*)	Excellent or Good				Fair or Poor				Total	
	Posterior				Posterior					
	Anterior	Type I	Type II	Types III to V	Anterior	Type I	Type II	Types III to V	Excellent or Good	Fair or Poor
0 to 15	1	6	0	0	0	0	0	1	7	1
16 to 30	2	9	2	4	0	2	6	19	17	27
31 to 45	2	2	2	2	0	5	4	21	8	30
46 to 60	0	1	3	0	0	2	3	8	4	13
61 to 80	0	2	0	0	0	1	2	4	2	7
Totals	5	20	7	6	0	10	15	53	38 (116)	78

* Five cases had a follow-up period ranging from eight and a half years to nineteen years and four months.

Cases with poor results: One patient was operated upon seven days after injury. In another a simple suture fixation of the fragment of the acetabular rim was made, but the position of the fragment could not be maintained.

It will be seen that six of the nine closed reductions with fair or poor results fall into the unfavorable categories of delayed reduction (two cases) and not reduced (4 cases). All six of the patients treated with open reductions had had several attempts at closed reduction, greatly delayed open reduction, or technical error in reduction. Consequently, while this series does not prove that open reduction is contra-indicated, it does demonstrate the relative effectiveness of early closed reduction.

The stability of the reduction in the cases with good results was complete, even in the absence of anatomical reposition of the posterior fragment. The seven good results did not bear out the experience of Urist [13] that "Reduced dislocations, with unreduced

TABLE XIV

ANTERIOR AND POSTERIOR DISLOCATIONS OF THE HIP
Period before Full Weight-Bearing Compared with Outcome

Time in Months	Anterior		Posterior Type I		Posterior Type II		Posterior Types III, IV, and V		Totals	
	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor	Excellent or Good	Fair or Poor
1	1	0	10	4	1	0	1	2	13	6
2	0	0	6	3	1	1	0	4	7	8
3	0	0	3	2	1	3	2	15	6	20
6	1	0	0	0	4	4	2	6	7	10
9	0	0	1	0	0	4	1	8	2	12
12	2	0	0	0	0	1	0	8	2	9
Miscellaneous *	1	0	0	1	0	2	0	10	1	13
Total	5	0	20	10	7	15	6	53	116	

* Miscellaneous, 14 cases: 4 unknown; 2 unrecognized; 2 irreducible; 3 arthrodesed; 1 reconstructed; 2 poor results (these patients are still on crutches).

FIG. 15-A FIG. 15-B FIG. 15-C

S. M. 439-380. Six years old. This was a Type V dislocation with a fracture of the femoral head. The result was fair.
Fig. 15-A: The patient was injured in an automobile accident June 18, 1935.
Fig. 15-B: The dislocation was reduced by traction June 19, 1935. The patient was in an abduction frame for three months and was able to walk after that.
Fig. 15-C: Roentgenogram made thirteen years and five months later. The head fragment had evidently become re-attached to form an exostotic mass blocking full flexion and adduction motion. Because of this the case was rated as fair. No surgical treatment was advised.

TABLE XV

INCIDENCE OF ROENTGENOGRAPHIC JOINT CHANGES IN SEVENTY-EIGHT FAIR OR POOR RESULTS

Type of Dislocation	Avascular Necrosis	Traumatic Arthritis	Myositis Ossificans	Miscellaneous *	Total Fair or Poor	Total in 116 Cases
Anterior	0	0	0	0	0	5
Posterior						
Type I	3	2	1	4	10	30
Type II	6	6	1	2	15	22
Type III	7	14	0	3	24	28
Type IV	8	11	0	0	19	20
Type V	3	4	0	3	10	11
Total	27	37	2	12	78	116

* Miscellaneous, 12 cases: 7 unknown; 2 excellent; 1 good roentgenographic rating; 1 fused; 1 irreducible.

but significant fracture of the rim of the acetabulum remaining, were followed by degenerative changes in the joint". He advised that anatomical reposition be accomplished by open operation. Anatomical apposition of a fragment in a joint fracture is a generally desirable objective, often achieved only with difficulty. No apposition would obviously be better than replacement with incongruous apposition to the head. The harmful potentials of the surgical approach, especially the risk of increasing vascular damage, should be considered before open operation is undertaken. On the other hand, the removal of comminuted fragments, which may not show on the roentgenograms, or the restoration of a posterior lip in an otherwise unstable reduction, can only be assured by open operation.

The unsatisfactory results in this series of open reductions indicate that, if performed at all, the operation should be carried out promptly.

Type III: Of a total of twelve open operations, good results were found in three cases in which the loose fragments had been removed from the joint; in a total of sixteen closed reductions there was only one good result. This serious fracture-dislocation presents a high proportion of fair or poor results, regardless of the method of treatment used.

The very nature of this injury makes it probable that there are loose fragments in the joint. While numbers are small, the three good results in twelve open reductions compared with one good result in sixteen closed reductions demonstrate the value of earlier operation and scrupulous removal of loose pieces of bone.

Type IV: In twenty cases of this type there were fair or poor results in nineteen. This type, therefore, presents a poor prognosis for hip-joint function, whether treated by open or closed methods.

The only good result was in the group treated by closed reduction. In this case, a seventeen-year-old male (Figs. 11-A to 11-D), the acetabular fracture was through the triradiate area. The superior weight-bearing portion of the acetabulum was preserved, although a large posterior lip fragment was displaced posterosuperiorly. This patient had pain for three years and then became symptom-free except for some aches or discomfort after dancing. He was in the tank corps in World War II. The follow-up period was twelve years and nine months. This is the one case in which the rating was raised one grade during the follow-up period.

The nature of the injury in Type IV fracture-dislocations makes a poor result almost certain because of the disruption of the acetabulum.

Type V: In nine cases of this type there was one good result. Both cases with open reductions had poor results. In neither instance was the head fragment excised. The case reported by Gordon and Freiberg, in which the loose fragment was excised, probably

TABLE XVI

RESULTS IN SEVENTY-FOUR CASES WITH DISLOCATION ONLY COMPARED WITH RESULTS IN FORTY-TWO CASES WITH DISLOCATION AND ASSOCIATED BONE AND NERVE INJURIES

Type	Excellent or Good		Fair or Poor		Total
	Dislocation Only	Other Injury	Dislocation Only	Other Injury	
Anterior	1	4	0	0	5
Posterior					
Type I	16	4	9	1	30
Type II	2	5	10	5	22
Type III	3	1	20	4	28
Type IV	0	1	7	12	20
Type V	0	1	6	4	11
Total	22	16	52	26	116

points to the best management. It is hoped that experience with more cases treated in this manner will establish a better outlook.

Length of Time before Operation according to Type and Result (Table XI).

The number of cases is too small and the types are too scattered to make the differences significant. Many of the operations were performed after the first week. With the exception of good results in three patients with Type III dislocations operated upon in the first week with excision of the loose fragments, the results appear to be determined by the type of injury rather than by the length of time between injury and surgical procedure. However, good clinical judgment would hardly condone unnecessary delay when open reduction is indicated. In one case in which reduction and arthrodesis were done three months after dislocation there had occurred irremedial proliferative, degenerative, and attritional changes involving the head and acetabulum.

Operations Other than Open Reduction (Table XII).

Hip surgery other than open reduction was performed in eight patients (Table XII). Four arthrodeses gave good results, but the results of three arthroplasties and one reconstruction operation were poor. A number of the poor results were in patients who had refused operation. Arthrodesis was usually advised because it offered greater assurance of a painless, stable hip.

These results confirm the experience of Phemister [9] that arthrodesis is the procedure of choice. He ascribes the poor results of arthroplasty to aseptic necrosis from the extensive stripping of the capsule entailed by the procedure.

The experience in this series does not permit significant comparison of the merits of arthroplasty and arthrodesis. Of four arthroplasties, two failed because of infection and two because of excessive new-bone formation. These poor results could be ascribed to technical failure. The four arthrodeses permitted unprotected weight-bearing after five months in one case, after six months in two, and after ten months in one case. Clearly the method of arthrodesis was more successful in this group.

Evaluation of the results of arthroplasty and arthrodesis in this type of patient depends upon many variable factors. What one surgeon or one patient may consider a good result may not satisfy another surgeon or patient. A patient's satisfaction is not always proportionate to function. Some arthrodeses are failures after several attempts. Some surgeons proscribe arthrodesis because backache, sometimes with radicular pain, later occurs. However, some patients who have had arthroplasty of the hip also have back pain, because of stiffness or instability, and others may require reoperation. Until sig-

nificantly large, comparable, and critically evaluated series are available, we believe the choice of treatment should be based largely upon the surgeon's estimate of the amount of correction he can obtain, taking into account the patient's age, occupation, satisfaction with the probable benefits, and adaptation to the probable handicaps of the chosen method.

Age Related to the Type and Outcome

When the 116 cases classified according to type and results are divided into age groups, it is seen that differences in results of the various types of dislocations for the series as a whole are borne out for individual age groups (Table XIII). Differences ascribed to type cannot, therefore, be due to accidental differences in age incidence in the various types. This is further confirmation of the significance of the results in the different types of injury.

Dislocations of the Hip in Children

Eight patients of an initial series of seventeen cases of dislocation in children from six to fourteen years of age were physically and roentgenographically examined. The time of follow-up was from a year and one month to nineteen years and four months; the average follow-up period was nine years and ten months. Two cases are not included in this group; these were the patients previously mentioned, who reported by telephone that they were asymptomatic, ten and thirteen years after the dislocation respectively.

One of the eight dislocations was anterior and showed an excellent result.

Six dislocations were posterior, Type I; they also presented excellent results.

There was one Type V dislocation in a child ten years of age. The last roentgenogram, made thirteen years after the dislocation, revealed a large exostotic mass of mature bone, based on the antero-inferior aspect of the head and margin of the head and neck. The cartilaginous joint space was normal. There was no evidence of avascular necrosis or traumatic arthritis. There was some limitation of hip flexion and adduction. This was believed to be due to the exostosis, presumably formed by re-attachment of the fragment of the femoral head. No treatment was advised. The result was rated as fair on the basis of the deformity of the non-weight-bearing portion of the head, slight irregularity of outline of the head, and the blocking of full flexion and adduction motion (Figs. 15-A to 15-C).

Eight of an initial series of seventeen children in the total series of 204 traumatic dislocations of the hip are known to be without evidence of avascular necrosis. One of the eight showed changes ascribed to traumatic arthritis.

Interval before Full Weight-Bearing Compared with Outcome

The outcome of the different types is charted against the period before full weight-bearing was resumed (Table XIV). The results in the five anterior dislocations, all excellent, and in the miscellaneous group, are excluded from the comparison.

Analysis shows that both the outcome and the length of time before weight-bearing seem to depend upon the type of injury. There is no evidence that the time when weight-bearing was begun in any given type of dislocation determined the outcome.

Those cases with longer periods of protection from weight-bearing did not show an increased proportion of better results. All but two of the patients with excellent or good results were walking by the end of six months, and all but four resumed full weight-bearing at the end of three months.

It is important to realize that in this series there was no arbitrary rule for the time of resumption of weight-bearing. The time varied with the individual surgeon, the patient, the apparent severity of the injury, and the presence of pain. Stuck and Vaughan list the times of protection from weight-bearing advised by many authors, and state that only in the last decade has it become recognized that early weight-bearing is unsafe. Potts and Obletz point out that the process of re-organization is slow, and that the period of two to

TABLE XVII

INCIDENCE OF ASSOCIATED INJURIES IN POSTERIOR DISLOCATIONS COMPARED WITH RESULTS

XVII-A

Posterior Dislocations, All Types

Results	Associated Injury: No	Yes	Total
Excellent or Good	21	12	33
Fair or Poor	52	26	78
Total	73	38	111

XVII-B

Incidence of Associated Injury by Type

Type	Associated Injury: No	Yes	Total
I	25	5	30
II	12	10	22
III to V	36	23	59
Total	73	38	111

XVII-C

No Associated Injury
Results by Type

Type	Excellent or Good	Fair or Poor	Total
I	16	9	25
II to V	5	43	48
Total	21	52	73

XVII-D

Influence of Associated Injury on Results
Types II to V Combined

Associated Injury	Result: Excellent or Good	Fair or Poor	Total
No	5	43	48
Yes	8	25	33
Total	13	68	81

three years of recumbency required would be difficult to enforce. This question will be discussed after an analysis of the roentgenographic changes observed.

Roentgenographic Joint Changes in the Various Types of Dislocation

The incidence of roentgenographic changes ascribed to avascular necrosis, traumatic arthritis, and myositis ossificans in the seventy-eight patients with fair or poor results is tabulated by type in Table XV. If a miscellaneous group of twelve cases is excluded, there are sixty-six cases tabulated under one or another of the above categories. There are twenty-seven patients with avascular necrosis and thirty-seven with traumatic arthritis. Two instances of severe myositis ossificans were encountered.

Avascular Necrosis

The distribution of the sixty-four cases with fair or poor results due to moderate to severe changes of avascular necrosis and traumatic arthritis depends upon the type of dis-

TABLE XVIII

DISTRIBUTION BY TYPE OF ASSOCIATED NERVE INJURIES IN 204 DISLOCATIONS OF THE HIP

Type of Dislocation	No. of Cases	Nerve Injuries: Sciatic	Peroneal	Total Nerve Injuries
Anterior	18	0	0	0
Posterior				
Type I	71	1	6	7
Type II	38	0	3	3
Type III	36	1	9	10
Type IV	26	1	4	5
Type V	15	0	1	1
Total	204	3	23	26

location. These sixty-four cases comprise 55 per cent. of the whole series of 116 cases. This kind of comparison, however, is misleading when applied to a given type of dislocation in which the incidence of these disabling changes may be higher or lower than the general average.

Armstrong's series of 100 cases showed an incidence of traumatic arthritis of 26 per cent. but this complication developed in only 15 per cent. of dislocations without fracture. The incidence in the group of dislocations with acetabular-rim fractures was 25 per cent.; in the group with fracture of the femoral head, 60 per cent.; and in the group with fracture of the acetabular floor, 100 per cent. The distribution of results in our series was similar.

Bancroft and Murray state that approximately 50 per cent. of traumatic dislocations of the hip show later degenerative changes in the hip joint. They are uncertain whether or not delayed weight-bearing diminishes the chances of degenerative changes.

Watson-Jones estimates that: "The complication arises in at least 20 or 30 per cent. of dislocations which are promptly reduced, and the incidence is much higher if the reduction is delayed".

Speed and Smith state that it has not been proved to their satisfaction "that a lack of weight-bearing will be effective in preventing an aseptic necrosis of the head". They state that, even if aseptic necrosis were anticipated, three to five years of non-weight-bearing might be required for complete revascularization, while it would still be extremely doubtful that a satisfactory joint would be preserved.

Banks' excellent review in 1941 of aseptic necrosis of the head of the femur following dislocation added nine cases to forty-two then recorded by other authors.

Full weight-bearing activity causes physiological pressures in the hip joint. Except with distracting pull, there is a positive pressure relationship between the head and acetabulum, varying with muscle tone and activity. There is no question that the softer the revascularized bone underlying the dense necrotic bone of the weight-bearing portion of the head, the less pressure it will take to cause collapse. Most writers are agreed that the cause of avascular necrosis is the tearing of some of the blood vessels and thrombosis of others at the time of injury and treatment. There is no substantial evidence that non-weight-bearing prevents the occurrence of avascular necrosis.

The purpose of non-weight-bearing is to avoid pressure that the head cannot withstand at a particular stage of revascularization. The real question appears to be, will non-weight-bearing, as effected by the use of crutches, preserve a hip, the seat of avascular necrosis, for future painless weight-bearing, or will the temporary use of crutches significantly postpone the onset of disabling symptoms.

Banks advises non-weight-bearing for a period of four to six months in order to produce disuse atrophy; if avascular necrosis has occurred, this will then be evident from the relatively dense necrotic head. He believes that, if necrosis has taken place, further protection is indicated. He also stresses the importance in cases where weight-bearing is resumed early, of a close follow-up to permit earlier treatment—putting the patient back on crutches—before excessive damage from pressure has occurred.

The authors believe that these two programs may be sound practice, but that the effect of the non-weight-bearing program upon the final outcome is uncertain. Since the large majority of the patients with fair or poor results had early warning symptoms within less than a year and many within less than six months, it appears more important to follow each case closely than to produce in every case extensive de-ossification by disuse.

Traumatic Arthritis

There were thirty-seven cases with disabling changes ascribed to traumatic arthritis, ten more than the number with avascular necrosis. Some of the unsatisfactory results among the cases with traumatic arthritis might have been ascribed to avascular necrosis if a more accurate roentgenographic diagnosis had been made. However, there are many cases in which the symptoms and the clinical and roentgenographic findings are more

readily explained by joint reactions to trauma. Thus, with traumatic synovitis there would be synovial hyperaemia and hyperplasia. Destruction of cartilage would take place as a result of subchondral and synovial proliferation and pannus formation. Attrition through motion of the joint would be augmented by incongruity of the joint surfaces or by loose pieces of bone. The hypertrophic underlying bone would give a sclerotic appearance in the roentgenograms. Continuing irritation results in marginal chondro-osseous production with formation of bony spurs and lips.

It seems hardly justifiable to attribute all the changes observed in the follow-up roentgenograms solely to avascular necrosis or traumatic arthritis. The authors believe that the various reactions of joints to trauma deserve further study.

It may be significant that the clinical rating was better than the roentgenographic rating in only eight cases in this series, while in sixteen cases the roentgenographic rating was higher. It would appear from this that more weight should be given to apparently minor pathological roentgenographic findings, and that the significance of reflex muscle spasm, protecting hip-joint motion at the extremes, should be more fully appreciated. Complaints of minor aches and pains should not be ignored. A thorough examination is indicated.

Results in Dislocations with and without Associated Bone and Nerve Injury

The relationship of associated injuries to outcome is shown in Table XVI.

Anterior Dislocations

There were excellent results in all five cases, although in four cases there were associated injuries. The group is too small for statistical comparison.

Posterior Dislocations

When the results in seventy-three cases without and thirty-eight cases with associated injuries are compared, regardless of type, no significant differences (Table XVII-A) are found.

Incidence of Associated Injuries in the Five Types of Dislocation

Analysis shows that associated injury occurred significantly less often in Type I than in other types. There was no significant difference between Types II and Types III, IV, and V combined (Table XVII-B).

No Associated Injury, Results by Type

When the cases with associated injuries are excluded, the results in Type I are significantly better than those in Types II, III, IV, and V combined (Table XVII-C).

Influence of Associated Injuries in Types II, III, IV, and V

The occurrence of associated injuries did not significantly alter results in Types II, III, IV, and V (Table XVII-D).

These findings are at variance with the conclusion of Stuck and Vaughan, who believed that a prolonged period of non-weight-bearing for the patient with associated injuries gave better results.

Associated Nerve Injuries

There were twenty-six nerve injuries in the total group of 204 dislocations (Table XVIII). There were no nerve injuries in the group with anterior dislocations. The number is so small and distribution among the posterior types is so scattered that no significance can be attached to the incidence among posterior types. It is probable that in a few of the cases, peroneal palsy occurred during traction or plaster-cast fixation.

Results in Cases with Nerve Injuries

Of the three cases with complete sciatic-nerve injury, no recovery occurred in two after four months, and in the other after seventeen months. Fourteen patients with injury to the peroneal nerve recovered in from three months to two years. One patient

showed partial recovery after two years. Six patients were not improved after eight to thirty-two months. Results in two cases with peroneal palsy are unknown.

Six of the twenty-five patients with open reductions had an associated peroneal-nerve injury. Four of these peroneal palsies occurred in Type III dislocations. Of these, one recovered in six months; another in one year. The third partially recovered in fifteen months, and the fourth showed no recovery after eight months. In Type IV cases there were two patients with peroneal palsy; one recovered in five months, the other showed no return of function after thirty-two months. In none of these six cases was the nerve injury caused by a bone fragment. In two other cases, which were treated by open reduction, postero-inferior acetabular fragments were encountered immediately underlying the sciatic nerve. In spite of this, there was no evidence of nerve damage.

DISCUSSION

Since the purpose of this report is to present the results of a rather extensive survey of traumatic dislocations of the hip, only a small number of authors have been cited in connection with certain pertinent findings in this study. No attempt has been made to present a review of the fairly voluminous literature, which would make a lengthy article in itself.

It may be permissible to call attention to some characteristics of this type of study. A statistical analysis requires a minimal number of cases in each category with comparable data before a probability determination can be made. A survey of dislocations of the hip must begin with a large series, because a certain number of cases will not remain available for follow-up study, and because the subdivision of the series into the several types of injury must yield a sufficient number of cases in each category for comparison with the other categories. Not infrequently, numbers insufficient for comparison may indicate a trend; further experience with additional cases may show the "trend" to be either significant or misleading.

Surgeons with an understanding of the reactions of the joint to trauma may arrive at a correct conclusion before a significant comparison can be made through such a study as the one presented here. It is hoped that the establishment of even a few probabilities can help to confirm sound opinion and guide the surgeon to more fruitful fields of endeavor in care of the patient and in further study and analysis of this problem.

The authors especially wish to call attention to the lack of significant differences in outcome in Types III, IV, and V in this series. Yet there are good reasons for believing that the results in Type III may be improved by removing the loose fragments in the joint, as these appear to be one cause of the unfavorable results. In the one good result in this series, the fragments were removed before any attempt at reduction was made. In the cases with fracture of the acetabular floor, which is generally accompanied by fracture of the acetabular rim (Type IV), much time may be saved if the outcome is correctly evaluated and early arthrodesis or arthroplasty is performed. Some dislocations with fracture of the femoral head not involving a significant superior weight-bearing portion may be spared traumatic arthritis by removal of the fragment.

There is no suggestion that open procedures will save the joint from the changes inherent in avascular necrosis of the femoral head. However, in certain instances there is reason to believe that, if incongruity of the articular surfaces can be avoided by restoring the position of the fragments necessary for stability or by removal of loose fragments, it will be possible to reduce the incidence of traumatic arthritis. There are a certain number of cases in which this assumption has been borne out.

There is no reliable method of distinguishing between all changes incident to avascular necrosis and those due to traumatic arthritis, especially when a single roentgenogram is reviewed some time after the injury. When there are typical differences in density, the diagnosis is simple. Even so, the cause of destruction of the articular cartilage is difficult

to determine. It may be due to the proliferative changes of traumatic arthritis or to rapid attrition of the articular surface, consequent to the reduced viability of the cartilage which appears to accompany necrosis of underlying bone. In cases where avascular necrosis is undoubtedly present, proliferation of bone at the acetabular margin and especially at the femoral capital-cervical junction is frequently noted. This cannot be the result simply of compression of the soft revascularized cancellous bone by the necrotic, wedge-like, superior portion of the head which transmits the body weight to the femur. Rather the incongruity of such a femoral head provides the mechanical irritation which stimulates the proliferative responses of the tissues involved; the process is the same as that resulting from the incongruity which follows a joint fracture or results from a loose fragment in the joint. However, some distinction between the probabilities must be made or at least attempted in order to understand the processes and their roentgenographic manifestations and clinical implications.

CONCLUSIONS

Differences in the several types of posterior dislocation and their outcome are significant.

The length of time before full weight-bearing was resumed did not significantly affect the results in this series. On the contrary, both the results and the time when weight-bearing was permitted appeared to depend upon the type of injury.

Avascular necrosis and traumatic arthritis were the chief complications encountered in those cases with unsatisfactory results.

Associated injuries did not affect results in the series as a whole.

Of the cases with injury to the peroneal nerve, a scant majority recovered spontaneously.

Good management depends upon prompt recognition of the dislocation. Except in cases where the patient's condition is critical, or where another local injury must take precedence, treatment of the dislocation should be prompt and based upon a careful evaluation of the type of dislocation and the treatment indicated.

NOTE: Acknowledgment is made to Frederick J. Moore, M.D., of the Department of Experimental Medicine, University of Southern California School of Medicine, for assistance in the statistical analysis of the data presented.

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DISCUSSION

DR. SAM W. BANKS, CHICAGO, ILLINOIS: Time does not permit me to discuss all of the interesting and important material brought to our attention by Col. Dehne and Dr. Thompson. I shall confine my remarks primarily to the relationship between vascular changes in the femoral head and ultimate function in a hip which has sustained a traumatic dislocation.

We are impressed with the unfavorable prognosis as demonstrated by some of the cases in these two reports. Considerable thought should be given to the problem of improving the prognosis in such cases.

I have had no personal experience with the combination of injuries reported by Col. Dehne. It is difficult to understand how a major injury like a traumatic dislocation of the hip can go unrecognized. Primary reduction of a dislocation as soon as it has been recognized may be difficult, but it can be accomplished by one method or another. Results in such cases should be comparable to those in which a traumatic dislocation is not accompanied by fracture of the femoral shaft. A primary arthrodesis of the hip is probably the treatment of choice when the dislocation has remained untreated and late open reduction must be performed, since necrosis of the femoral head is likely to have begun.

There is always difficulty in interpreting roentgenograms; I think that one of the first x-rays, for example, presented by Col. Dehne, shows a necrotic head which has undergone replacement to a varying degree.

Dr. Thompson's paper is timely and significant. It is the first statistical analysis of a large series of traumatic dislocations of the hip which offers some indication as to the incidence of aseptic necrosis. Necrosis of the femoral head developed in twenty-seven of 116 hips, and end results in these cases were rated as fair or poor. All twenty-seven hips were painful, and all had limitation of motion due to an arthritis secondary to the necrosis. Although many of the patients in this series did not bear weight for six to twelve months, the ultimate prognosis was essentially the same, regardless of the time when the patient resumed walking.

The end results might, in fact, have been predicted, for a devitalized femoral head cannot stand up under full weight-bearing. There is only one possible way to change the prognosis in this group of unfortunate patients. This is based upon early recognition of the necrosis of the femoral head and prevention of weight-bearing until the necrotic head has been completely replaced.

This program is recommended for treatment of traumatic dislocation of the hip. We do not know at this time what the results would be in a significant series of patients, but from what we know of necrosis in other conditions the following program appears to be justified:

1. Closed reduction is to be performed immediately.

2. Since the highest incidence of traumatic arthritis occurs in patients with fractures of the acetabulum, it is important that fragments of the acetabulum be restored accurately, either by closed or by open reduction.

3. Bed rest must be enforced for a period of three to six weeks, or longer if there are associated injuries.

4. Walking on crutches may be permitted for six months after this. The patient should wear a half-inch lift on the shoe opposite the involved extremity, so that he does not bear weight on that side and the limb can dangle in full extension. This is not for the purpose of preventing necrosis. Necrosis occurs at the time of the injury and results from rupture or thrombosis of blood vessels supplying the head of the femur.

5. After six months, steroscopic roentgenograms of the hip should be made to determine, if possible, whether the head has undergone uniform atrophy of disuse. If it has, the head is living and full weight-bearing can be resumed. Check-up roentgenograms of the hip should be obtained at three-month intervals for two years in order to verify this diagnosis. If the head appears normal in density at six months, but that density is greater than that of the surrounding living bone which has undergone atrophy of disuse, the head is necrotic. If there are irregular areas of density, necrosis has occurred but the head is undergoing revascularization. The head which has been dead since the injury cannot be said to begin to show aseptic necrosis. Mottling of the head is roentgenographic evidence of partial replacement. If necrosis has taken place and weight-bearing is resumed at six months or even at twelve months, the femoral head will collapse and the result will be unsatisfactory, as in the twenty-seven cases in the series reported by Dr. Thompson. Weight-bearing must be avoided until roentgenograms show complete replacement. The necrotic femoral head will undergo spontaneous replacement, but this process requires a minimum of three years. Ways must be found to hasten this process.

Dr. Phemister, in his Instructional Course Lecture, discussed several cases of necrosis in which rapid replacement was obtained after the insertion of tibial bone grafts through the neck and head of the femur to the articular surface. If roentgenograms taken six months after a traumatic dislocation of the hip show a necrotic head, one might be justified in performing this operation.

The Academy should appoint a committee to study traumatic dislocations of the hip. No one surgeon will accumulate a series of cases sufficiently large to answer some of the problems which result from this injury, especially the efficacy of present methods of treating vascular complications.

DR. MARSHALL URIST, LOS ANGELES, CALIFORNIA: Dr. Thompson and Dr. Epstein have reported 204 cases and 116 end-result examinations, the world's largest single series of dislocation of the hip joint. Their report will demand the attention of every future student of this problem. Dr. Dehne and Dr. Immermann have completed an exhaustive study of a rare combination of injuries,—fracture of the shaft of the femur associated with dislocation of the hip joint. The main problem was the management of the dislocation of the hip.

These reports are the vanguard of more to come. We may soon expect a high state of development in our knowledge of dislocation of the hip joint. In a recent notice in the British volume of *The Journal of Bone and Joint Surgery*, it was announced that a survey is being made in England of a series of cases from the entire country.

One of Dr. Thompson's most important observations is the good results in seven patients with posterior rim fractures of considerable size which were not treated by open operation. Nine similar cases showed only fair or poor results under conservative treatment. Further studies are necessary to determine the exact indications for surgical treatment of rim fractures. The end results in the fracture-dislocations of the hip are the same as for other weight-bearing joints with one important difference,—the vulnerable structure of the blood supply to the head of the femur. The superior portion, the weight-bearing portion of the head of the femur, receives its blood supply through blood vessels which enter at the attachment of the retinacula of Weitbrecht and the posterior reflected capsule of the hip joint.

We have personally examined the hip joint at open operation in nineteen fracture-dislocations,—fifteen in the United States Army in England, France, and Germany in 1945, and four in civilian practice since the end of the War. These were open reductions upon large single fragments of comminuted rim fractures in cases in which the dislocations had been reduced within a few hours after the time of the injury. On examination of the interior of the joint within a few days, hemorrhages in the substance of the retinaculum of the hip joint were found in two cases. This condition was not found in any of the other thirteen cases. Two years later, avascular necrosis of the head of the femur was found in only these two cases. We have recently seen a third case and photographed this lesion at open operation.

The incidence of avascular necrosis in the individual patient may be prognosticated when a thrombus is found in the lake of areolar tissue beneath the attachment of the retinacula. In order to evaluate treatment of 100 cases, or even 1,000 cases, by statistical methods, and to ascertain indications for: (1) surgery versus conservative treatment; (2) traction versus immobilization; and (3) early versus late weight-bearing, it is absolutely essential that a clear distinction be made between degenerative arthritis, avascular necrosis, and other causes of poor end results. Degenerative arthritis is a progressive destructive lesion, presenting defects on both sides of the joint. Avascular necrosis is basically an infarction involving only one side of the joint. Avascular necrosis should be managed by such specific treatment as intramedullary bone grafts, recently suggested by Dr. Phemister, and restricted weight-bearing. Obviously both complications may exist together in extensive fracture-dislocations; in such cases early arthroplasty or arthrodesis may be indicated.

LIEUTENANT COLONEL ERNST DEHNE (closing): I want to thank the discussors for their interest. I am in perfect agreement with Dr. Banks that the subject of aseptic necrosis, which was not the subject of my paper, is a very important one and needs further investigation. I do not agree with some of his interpretations. In fractures of the head of the femur or in fractures of the carpal navicular, calcium density of the avascular fragment is evident after about six weeks, and revascularization of this fragment takes place much later, after four to twenty-four months. The roentgenogram discussed by Dr. Banks may give the appearance of replacement, but in my case this was seen four months after the injury. This would not suggest avascular necrosis but simply degenerative changes such as those seen in malum coxae senilis.

Dr. Banks' point that decalcification of the hip denotes a living head is important. In one of our cases in which the head eventually collapsed, decalcification was present one year after the reduction and the head collapsed only secondarily. I would suggest that this is the result of a secondary change occurring under the stress of weight-bearing.

Finally, arthrodesis of the hip may be the preferred treatment in cases where the dislocation has been overlooked for a long time. However, in the one case, followed for three years, in which we shortened the femur and obtained good motion and a painless hip, I feel we achieved a better result than would have been possible with an arthrodesis.

DR. VERNON P. THOMPSON (closing): Dr. Epstein and I feel very fortunate in the choice of discussors of our paper. Dr. Banks and Dr. Urist have given us freely of their time and even went so far as to let us know what they were going to say. I wish to thank them very much.

(*Continued on page 792*)

FRACTURE-DISLOCATION OF THE HIP

Report of an Unusual Case

BY T. F. RIGGS, M.D., AND R. C. SLOCUM, M.D., PIERRE, SOUTH DAKOTA

From the Pierre Clinic, Pierre

A dislocation of the hip with an associated fracture of the neck of the same femur is a condition brought about only by extreme forces applied in a particular direction. This is admirably achieved in the front seat of a modern, high-speed automobile, with the passenger's hips and knees flexed to 90 degrees and the rigid instrument panel in position to do damage should the passenger be thrown forward. This case is presented as an example of such an injury,—a very unusual fracture-dislocation which lent itself to the method of treatment described.

On August 14, 1949, Mrs. R. B. was riding with her husband in a truck when a collision occurred with an automobile. The patient was thrown violently forward, striking her left knee on the instrument panel.

She was brought immediately to the Hospital where the examination revealed a well developed female, fifty-nine years old, in acute distress. There was an obvious deformity of the left lower extremity, with shortening and external rotation. There was a large hematoma of the upper thigh, and pressure exerted over the trochanter was quite painful. No evidence of injury to the sciatic nerve was present. Blood pressure was 90 systolic. No abnormalities were noted in the heart, lungs, or thoracic cage, although she complained of pain across the lower chest anteriorly.

Roentgenographic examination revealed a fracture-dislocation of the left hip, and a fracture of the posterior lip of the acetabulum (Fig. 1). The fracture line extended from a point distal to the lesser tro-

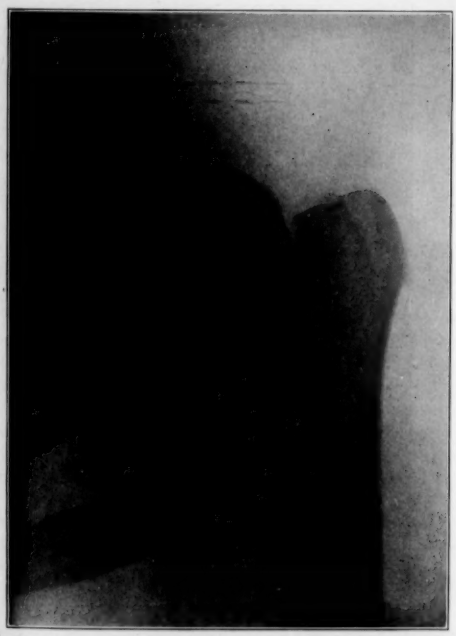

Fig. 1

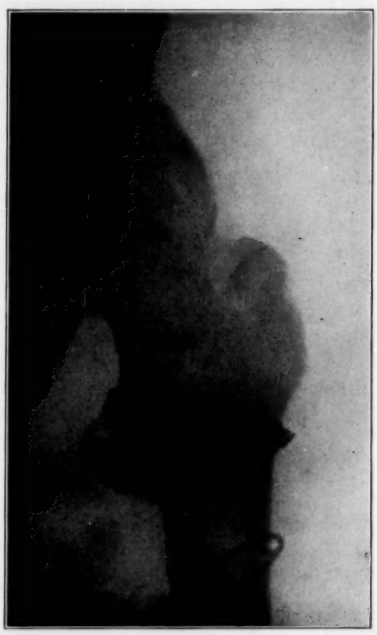

Fig. 2

Fig. 1: Roentgenogram made the morning after admission, showing the dislocation of the femoral head and the fractures of the femoral neck and shaft and posterior rim of the acetabulum.

Fig. 2: September 3, 1949. Roentgenogram made three days after the operation.

chanter to the junction of the neck with the greater trochanter. There was an iliac dislocation of the head, with the attached lesser trochanter directed anteriorly and upward by the pull of the iliopsoas muscle, and there was considerable over-riding of the shaft of the femur.

The left lower extremity was placed in Russell's traction with twenty pounds of weight. Repeated portable-unit roentgenograms, over a two-week period, failed to reveal any improvement.

An open reduction seemed the only method of treatment which might offer a good result. On September 1, 1949, the left hip joint was exposed through the Smith-Petersen approach. There was extensive hemorrhage into the surrounding tissues. The bone fragments were found as had been previously determined by the roentgenograms. An incision, two centimeters long, was made longitudinally through the iliofemoral ligament, and the acetabulum was explored with the finger. It was found to be empty and the fracture of its posterior rim, previously noted in the roentgenograms, was felt; the ligamentum teres had been torn at the site of its attachment to the acetabulum. Bone-holding forceps were attached to the lesser trochanter, and, with considerable manual traction, the head was replaced in the acetabulum. At the fracture site, the shaft of the femur was found to be unusually narrow; and it was felt that any internal fixation would be unstable and might split the shaft. While traction was applied to the foot and the proximal fragment was held in place with a clamp, a Parham band was placed about the shaft of the femur and the proximal fragment, just proximal to the lesser trochanter. The band was not made tight, since there was no chance of its slipping and since there would be less likelihood of bone necrosis. During the procedure, the patient received blood and saline solution; and at no time did her blood pressure fall below 100 systolic, 70 diastolic. After the operation, the patient received prophylactic treatment with penicillin. The limb was placed in Buck's extension, with sand bags supporting it laterally (Fig. 2).

On September 13, 1949, the patient was placed in well-leg traction casts, maintaining the left hip in abduction.

A roentgenogram taken on September 23, 1949 (Fig. 3) revealed that there had been some changes in the relation of the two fragments since the time of surgery. With the casts in place however, there appeared to be no further change and the position was considered to be satisfactory.

After the casts had been applied, it was observed that the patient's legs had swollen considerably. The casts were then split along their lateral borders and were spread. Thrombophlebitis had developed and the patient was placed on intravenous injections of 125 milligrams of heparin, given at eight o'clock in the morning and at eight o'clock in the evening; 75 milligrams of heparin given at noon and at four o'clock in

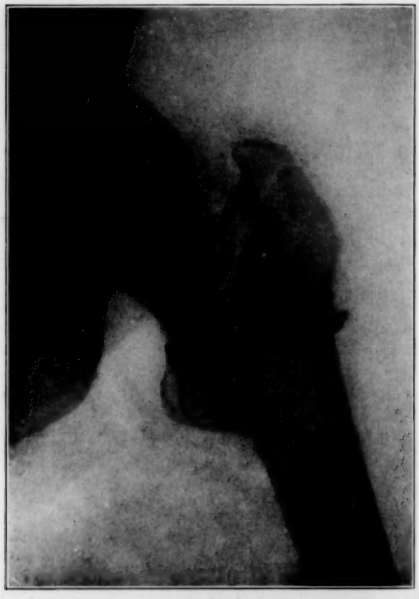

FIG. 3

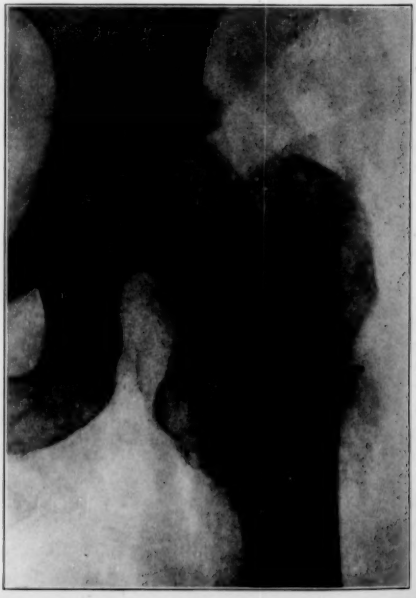

FIG. 4

Fig. 3: September 23, 1949. Roentgenogram shows slight displacement of fragments.

Fig. 4: November 12, 1949. Roentgenogram, seventy-four days after the operation, demonstrates callus formation about the lesser trochanter and between the fragments. There is noted also slight erosion of the shaft of the femur by the Parham band.

FIG. 5

March 14, 1950. Roentgenogram, nine months after the injury, shows fragments apparently healed in a moderate coxa valga.

the afternoon. Clotting times were checked; the patient seemed to maintain a satisfactory prolongation. After the institution of the heparin therapy and the splitting of the casts, there was a slight reduction in the amount of swelling of the lower extremities, particularly below the knee. A brawny oedema of the lateral aspect of both thighs was noted.

The hemoglobin determination at this time was 10.2 grams, which increased to 12 grams after transfusion of 1000 cubic centimeters of blood. There was some decrease in the swelling of the thighs following the blood transfusion.

On October 13, 1949, twenty days after their application and forty-three days after the operation, the well-leg traction casts were removed. The patient was found to have good range of passive motion in the left hip, without pain. The swelling of the legs had almost completely disappeared. The amount of heparin injected was gradually decreased and was completely discontinued on October 18, 1949. On October 20, 1949, the patient was allowed to be up in a wheel chair; and, with the dependent position of the legs, swelling and a purplish discoloration of the legs occurred which were partially controlled by elastic bandages. On November 3, 1949, sixty-four days after the operation, the patient was allowed to use the "walker" without weight-bearing on the left leg. Shortly thereafter, she was allowed to use crutches provided that she put no weight on the left leg.

A roentgenogram (Fig. 4) with stereoscopic views, showed the position to be satisfactory. There was a large amount of callus about the lesser trochanter and a smaller amount between the two fragments in the region of the neck of the femur. This prolific callus formation was felt to be a fairly solid support with the Parham band, which, it should be noted, had caused slight bone erosion along the shaft of the femur.

On November 16, 1949, the patient was discharged and sent home for further convalescence.

In December 1949, she was seen for a routine examination. She had then an almost complete range of motion in the left hip, without pain. There was, however, a moderate swelling of the legs with cyanosis when they were in a dependent position. This, as before, was partially controlled by elastic bandages. Roentgenograms showed further callus formation. She was encouraged to use her crutches more, but was not allowed weight-bearing.

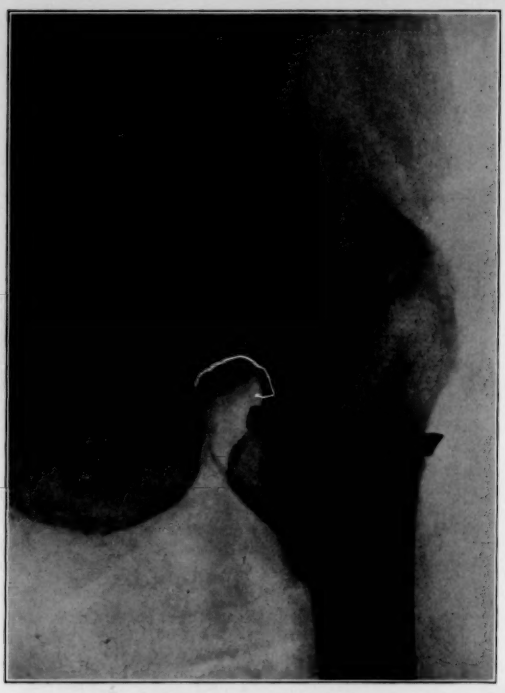

FIG. 6

December 15, 1950. Roentgenogram, sixteen and one-half months after the operation, shows excellent callus formation, good position, and the Parham band in place. There is however, evidence of avascular necrosis of the femoral head in terms of increased density, irregularity of the articular surface and joint space, and some flattening of the weight-bearing portion of the head of the femur.

In February 1950, the patient was seen, complaining of back pain. This was caused by an unrelated hypertrophic arthritis of the spine. A roentgenogram showed good union with no vascular changes in the head of the femur, and she was allowed partial weight-bearing with crutches.

In March 1950, the patient had no complaints and had a complete range of motion in the hips, without pain; however, the moderate swelling of the legs persisted. Roentgenograms of the hip (Fig. 5) revealed the fracture apparently healed in moderate coxa valga and showed no definite evidence of avascular necrosis of the head. The patient was told to gradually increase weight-bearing, using a cane for support.

The patient was last seen on December 15, 1950, sixteen and one-half months after the open reduction and the application of the Parham band to the left hip. She then reported that there was still some oedema of both lower extremities at the end of the day, which disappeared at night.

The physical examination showed dilatation of the veins in the lower right abdomen which was doubtless due to the accessory development of the veins following a previous deep thrombosis. The left side of the abdomen showed no such venous engorgement. The patient walked very well, although there was a slight limp noticed. She stated, however, that this was not due to pain.

Roentgenograms were made which showed excellent callus formation, good position, and the Parham band in place. Two small spicules were noted at the lesser trochanter and the acetabulum which did not seem significant. There was, however, some evidence of avascular necrosis of the femoral head in terms of increased density, irregularity of the articular surface and joint space, and some flattening of the weight-bearing portion of the head of the femur (Fig. 6).

DISCUSSION

ANALYSIS OF SUCTION-SOCKET WEARERS

(*Continued from page 649*)

of the muscles. As the muscles are tensed, the diameter of the stump increases greatly. The socket thus fits too loosely with the stump relaxed and is too tight with the stump tensed. Such stumps may require surgical revision.

The operation described by Harold Conn [a] is recommended. The Conn procedure effectively restores the muscles to their bone attachments and prevents excessive muscle retraction.

I would like to congratulate the authors on their excellent presentation.

[a] CONN, H. R.: Amputation Stumps of Lower Extremities: The Causes and Treatment of Prolonged Disability. Surg., Gynec., and Obstet., **43**: 524–528, 1926.

DR. ROBERT MAZET (closing): I thank the discussors for being so kind. There is really nothing to add except that I would like to point out that our tables vary a little from Dr. Thorndike's in that we adopted a six-month minimum period, and we do not include the intermediate group of partial wearers. We regarded anyone who was an alternate wearer as a member of the unsuccessful group,—the people whom we called successful were the people who were wearing the suction socket all the time and working in it.

THE RING APOPHYSIS OF THE HUMAN VERTEBRA

Contribution to Human Osteogeny. II

BY EDGAR M. BICK, M.D., F.A.C.S., AND JOSEPH W. COPEL, M.D., NEW YORK, N. Y.

From the Orthopaedic Service, Mount Sinai Hospital, New York City

In a previous paper on the osteogeny of the human vertebra, it was stated that the so-called epiphyseal ring, which is found during the growth period as a narrow cartilaginous mound lying on the rims of the cephalad and caudad surfaces of the vertebral body, took no part in its longitudinal growth, and was in fact misnamed.[1] It lay outside the true epiphyseal plates and actually most nearly resembled an apophysis of the traction type, responding to the attachments of the longitudinal and intervertebral ligaments of the spine. As in similar apophyses elsewhere in the skeleton, when it approaches maturity, it ossifies and finally fuses with the vertebral body.[1] This apophyseal resemblance had also been suggested by others, especially Schmid in his recent study of Scheuermann's disease,[2] but has not been histologically demonstrated. The verification of this observation has been seriously questioned by a number of investigators.[1]

In our earlier histological sections, the appearance of the vertebral ring apophysis was incidental to the primary study of enchondral growth, so that specimens had not

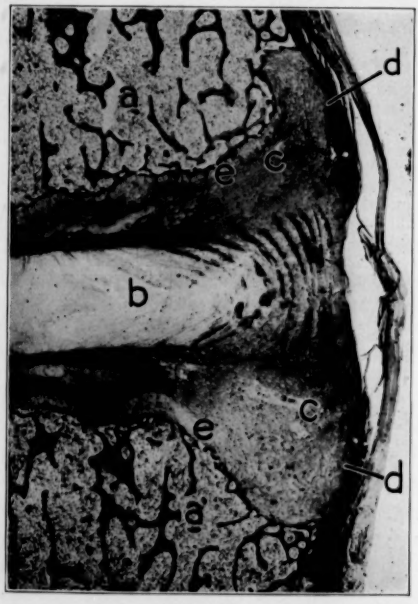

FIG. 1-A

FIG. 1-B

Six-year-old female. Lower thoracic vertebrae.

Fig. 1-A: Section from adjacent anterior corners of a sagittal cut.
a: Expanding enchondral ossification of the vertebral body.
b: Intervertebral disc and annulus fibrosus.
c: Area of condensation of calcified cartilage in the articular cartilage of the cephalad and caudad perivertebral depressions.
d: Insertion of fiber of anterior longitudinal ligament.
e: Epiphyseal plate.

Fig. 1-B: Central two vertebrae are those from which the histological sections were taken. The light shadow of the calcific condensation is visible anteriorly within the depression and at the level of the cephalad and caudad limits of the enchondral ossification mass. It is quite unusual to find x-ray evidence of the ring at this early age, but this case is not unique.

FIG. 2-A

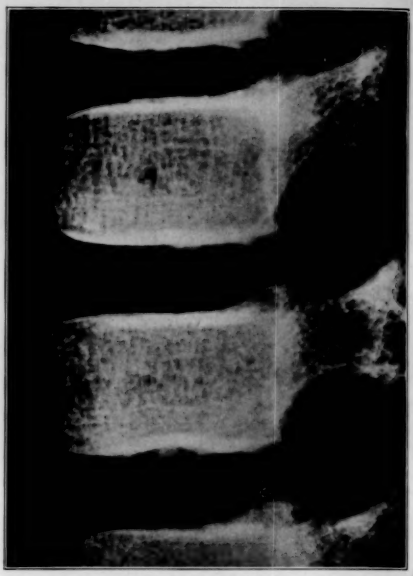

FIG. 2-B

Ten-year-old male. Lower thoracic vertebrae.

Fig. 2-A: In this section, condensation of cartilage within the depression and outside the epiphyseal plate is clearly seen. The insertion of fibers of the anterior longitudinal ligament at this level into the surface cells of the cartilage is particularly visible.

Fig. 2-B: In this x-ray film, calcification of the ring anteriorly was not dense enough to be visible, but there is a suggestion of it along the superior and inferior borders of the vertebrae more centrally. (This is of course a projection of circumferential densities.)

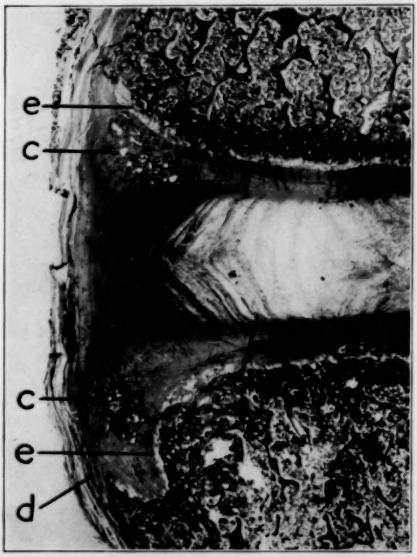

FIG. 3-A

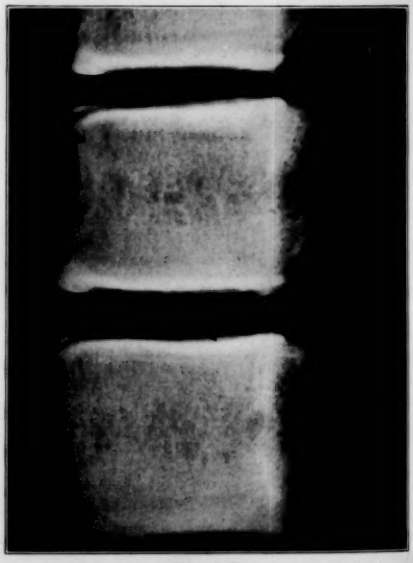

FIG. 3-B

Figs. 3-A and 3-B: Thirteen-year-old female. Lower thoracic vertebrae.

Fig. 3-A: In this section the first clear evidence of ossification appears in the ring (*c*). It is obviously well outside the line of the epiphyseal plate (*e*). Fibers can be easily seen branching away from the main line of the anterior longitudinal ligament and attaching to the cartilaginous depression at the site of formation of the ring (*d*).

Fig. 3-B: The ring in the x-ray film is obvious. Note that, as compared with Fig. 1-B, the vertebral-body mass appears to have spread toward the ring, filling in a large intervening radiolucent area of cartilage.

FIG. 4-A

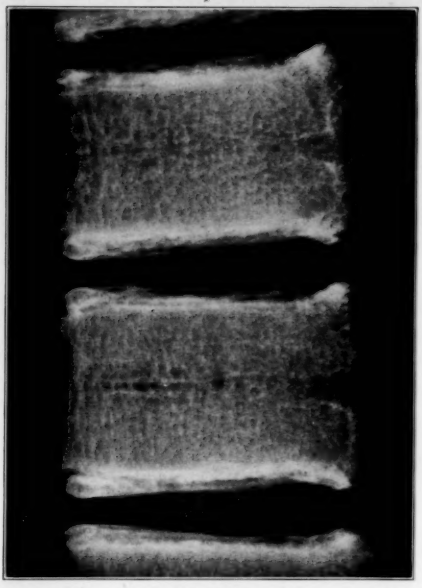

FIG. 4-B

Fourteen-year-old female. Lower thoracic vertebrae.

Fig. 4-A: Further ossification has taken place in the ring. Note that it is still outside the epiphyseal border of the growing vertebral-body mass and adds nothing to the longitudinal growth of the mass inside the periphery.

Fig. 4-B: The x-ray film shows the space between the ring and the body more densely occupied by the expanding bone mass of the latter.

been cut with its demonstration specifically intended. This left a certain hiatus in the evidence of an important aspect of vertebral development. This hiatus was particularly important, since it concerned the most controversial point in the problem. The study has been completed by gathering additional specimens of human vertebrae between the ages of six (the usual age of its earliest gross appearance), and eighteen (which has been found, contrary to previous reports[3], to be the age of its usual fusion), and preparing them to properly demonstrate the development of the ring.

The interest of the roentgenologists in the subject was expressed by an editorial which appeared in the *American Journal of Roentgenology* following the publication of our previous report.[4] Recognizing the validity of their helpful criticism, we made x-ray pictures of each new specimen after dissection and before cutting. The specimens included herein are taken from those of our collection in which corresponding x-ray films showed the visible presence of the ring.

DISCUSSION

Sections of human vertebrae were cut to exhibit the histology of the vertebral-ring apophysis. This ring was first called the "*Randleiste*" by Schmorl.[3] It is a narrow mound which more or less completely encircles the rims of the upper and lower surfaces of the

FIG. 5-A

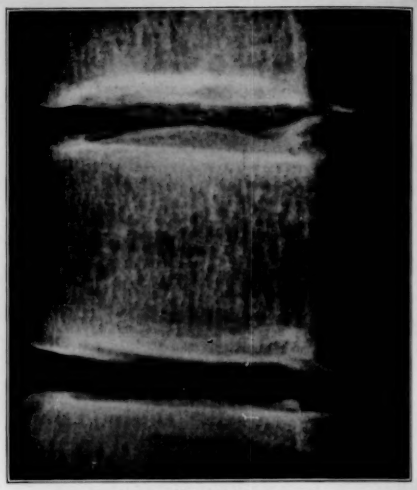

FIG. 5-B

Seventeen-year-old male. Lower thoracic vertebrae.

Fig. 5-A: In this section the ring has begun to fuse with the ossific mass of the body. It barely extends beyond the longitudinal reaches of the latter.

Fig. 5-B: The x-ray film shows almost complete fusion of the ring apophysis to the vertebral-body mass.

FIG. 6

Fig. 6: Eighteen-year-old female. Lower thoracic vertebrae.

Fusion between the ring apophysis and the vertebral-body mass is complete. It has expanded only its own relative size with growth of the body, but it has added nothing to the longitudinal growth of the vertebra. Its own expansion has been within the circumferential depression at the cephalad and caudad rims, has been within a cartilaginous anlage, and, except at the periphery, has not produced the articular cartilage of the vertebral body.

vertebrae. It may be lacking at the posterior margin. Its purpose has always been questioned, but it has been suggested, and our specimens demonstrate that it is the site at which branching fibers from the long intervertebral ligaments insert into the individual vertebra. These fibers by their function exert traction at their point of insertion.

The ring develops by a concentration of cells within the cartilaginous depression which surrounds the upper and lower rims of the growing ossific mass of the vertebral body. This depression is evident only histologically and roentgenographically. Grossly it is a radiotranslucent cartilaginous slight prominence following the margins of adjacent surfaces. This circle calcifies at about six years of age, begins to ossify at about thirteen years, and begins to fuse with the body mass of bone at about seventeen years. At eighteen

years, in each section we have studied, fusion is apparently complete. At about twenty years of age, the ring cannot be histologically identified. It is always covered by the same articular cartilage plate that covers the ends of the vertebra.

At all times until fusion begins, it develops outside the epiphyseal plate. It maintains its own relative rate of growth, commensurate with that of the body. It adds nothing to the longitudinal growth of the vertebra; in fact, it does not even lie connected with it except at its periphery. While developing in the peripheral osseous depression, it seldom extends more than a millimeter or two beyond the longitudinal range of the vertebra itself. Histologically speaking, it acts precisely as does an apophysis lying outside the line of longitudinal growth of its bone mass. In view of the attachment of the long vertebral ligament fibers, it may be classified as a traction apophysis. We therefore prefer to call it the vertebral-ring apophysis, or more simply, the vertebral ring.

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IRREDUCIBLE DISLOCATIONS OF THE KNEE JOINT

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From a review of the standard texts on the treatment of fractures and dislocations, it would appear that traumatic dislocations of the knee joint are readily reduced without difficulty. Thus Key and Conwell[1] state "all that is necessary is to have an assistant make traction on the leg while countertraction is made on the thigh, and the surgeon, by direct pressure on the bones, pushes or pulls the tibia back into place". As they have pointed out, the cruciate and lateral ligaments are more or less extensively ruptured. Accordingly, they do not advise open reduction, "as the ligamentous damage is so extensive that there is little chance of operative repair and the chance is not worth the risks incident to the operation".

There is, however, one type of dislocation in which open operation is not only advisable but also imperative, since reduction is otherwise impossible. It is the purpose of this paper to call attention to this type of dislocation and to record four such cases which have been admitted to the Orthopaedic Service of the Bridgeport Hospital during the past thirteen years.

CASE 1. A. L., male, aged fifty-three years, was admitted to the Hospital on February 20, 1937, shortly after having been struck on the outer side of the right knee by an automobile. The examination revealed an obvious lateral dislocation of the knee joint. Roentgenograms made immediately (Fig. 1) confirmed this diagnosis and excluded the possibility of any complicating fractures. Considerable swelling in and around the knee joint was present, with a transverse groovelike depression beneath the skin along the medial joint line. No nerve or vascular complications were noted.

Under general anaesthesia, reduction was attempted by traction and by direct manipulation. Most of the gross deformity could be readily corrected; full reduction, however, could not be secured, for the medial tuberosity of the tibia failed to return entirely to its normal position beneath the femoral condyle. It was observed that the groovelike transverse depression, noted prior to manipulation, became even more pronounced and gave the impression that the deeper capsular structures were caught and held within the joint.

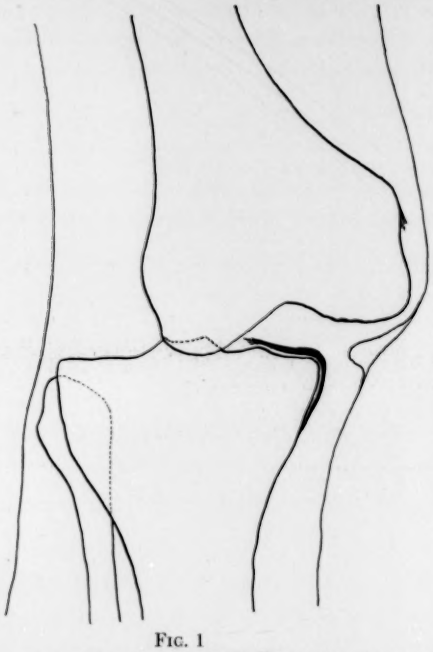

FIG. 1

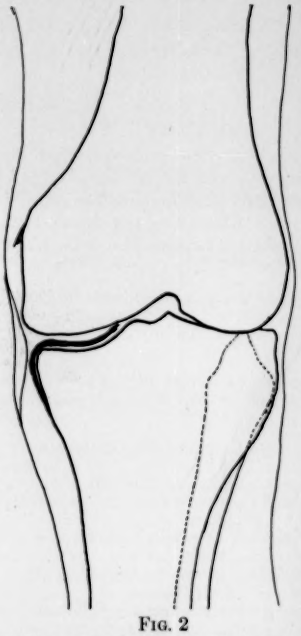

FIG. 2

Fig. 1: Case 1. A. L. Tracing of anteroposterior x-ray of right knee showing lateral dislocation. Dislocation was irreducible because of complete avulsion of the tibial lateral ligament and interposition of the capsuloligamentous flap within the joint. Characteristic depressed groove on the medial aspect of knee is clearly shown.

Fig. 2: Case 2. L. O'D. Tracing of anteroposterior x-ray of the left knee, showing incompletely reduced lateral dislocation with capsuloligamentous flap interposition. Note the well marked groove on the medial side of the joint.

Accordingly, a few days later the man was operated upon through a five-inch medial parapatellar incision. As soon as the subcutaneous tissues had been incised, the joint was found to lie wide open, without the interposition of any capsule or of any ligamentous structures. Much clotted blood was removed, and it was then apparent that the entire tibial collateral ligament with the adjacent capsule had been avulsed *en masse* from its attachment to the femoral condyle; and, as abduction of the knee had continued, the entire sheet of the capsule, together with the ligament, had been drawn into the joint where it fitted tautly, like a glove, over the articular surface of the tibial tuberosity. The whole picture was as though the femoral condyle had been forced through the capsule and ligaments at their upper attachment as in a "button-hole dislocation" of a metacarpophalangeal joint.

This capsuloligamentous flap was stretched so tightly over the medial half of the tibia that it could not be retracted until its posterior edge had been incised and freed. It could then be drawn out without difficulty. Although the cruciate ligaments were seen to be torn, the medial meniscus was undamaged and so was not disturbed. Reduction now was secured by simple adduction of the knee, after which the capsule and ligaments were reattached to the femoral condyle with a few silk and catgut sutures; and the wound was closed. A well fitting toe-to-groin cast was then applied with the knee in maximum adduction. This was removed after six weeks at which time physical therapy and active exercises were started. The patient left the hos-

pital one week later, walking with crutches. These were discarded shortly afterward; and, with continued physical therapy and active exercises, his motion gradually returned to normal. When last seen, five months after the operation, there was full range of motion of the knee with minimum anteroposterior instability but with no lateral instability.

CASE 2. L. O'D., male, aged seventeen years, was admitted to the Hospital on October 29, 1938, after having been injured in a football game in which he had been tackled violently from the side, injuring his left knee. The marked deformity which had been present originally had been corrected prior to admission. Examination revealed a swollen, painful knee without gross deformity. However, marked lateral instability was noted, together with a deep transverse groove along the medial joint line. Although x-rays showed what was reported by the roentgenologist to be a normal knee, without fracture or dislocation (Fig. 2), in

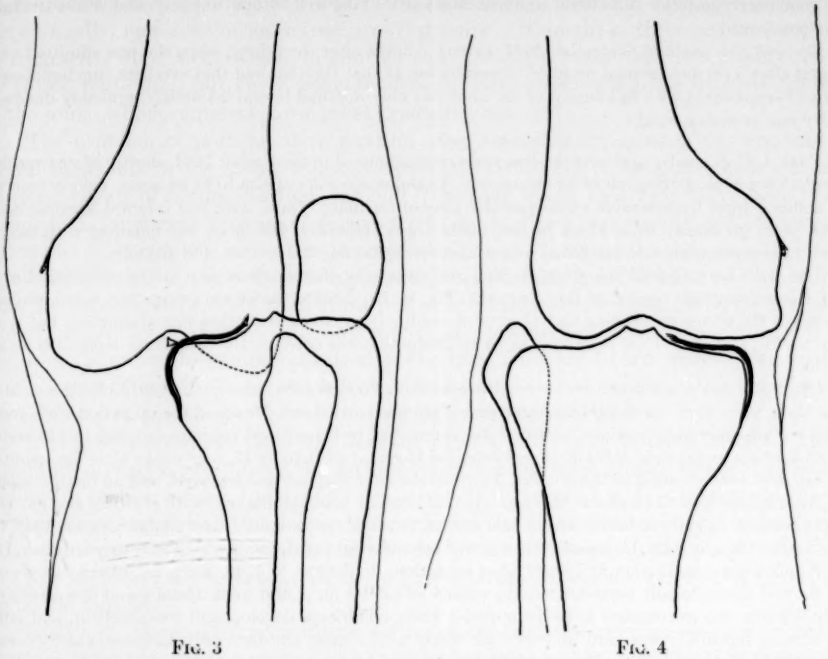

FIG. 3 FIG. 4

Fig. 3: Case 3. A. V. Tracing of anteroposterior x-ray of the left knee showing lateral dislocation with marked rotation of tibia and fibula. Depressed groove is largely obscured by obesity and swelling. A small fracture fragment has become detached from the intercondyloid eminence.

Fig. 4: Case 4. C. S. Tracing of anteroposterior x-ray of the right knee showing partial lateral dislocation with the interposition of the capsuloligamentous flap which prevented closed reduction. The groove is clinically obscured by obesity and swelling.

view of our previous experience with Case 1, the diagnosis of a lateral subluxation of the knee joint with invagination of the capsule was made. Two days later this was confirmed by operation, at which time the anterior cruciate ligament was seen to be torn, and the posterior half of the medial meniscus was found to be markedly loosened from its attachment, necessitating its removal. The capsule was drawn out of the joint, the dislocation reduced, and the ligament repaired. After the operation, a toe-to-groin cast was applied with the knee in maximum adduction. After two weeks, this was removed, and a new more closely fitting plaster cast was applied which remained on an additional four and one-half weeks. Knee motion gradually returned, and, on March 16, 1939, he was discharged from treatment, having regained full knee motion.

At a follow-up examination in September 1945, seven years after the operation, he reported that his knee was functionally perfect. He had been accepted for service in the Air Corps, had undergone flight training without difficulty, and had flown in the European Zone for some months without mishap. Clinically, aside from the operative scar, his knee was normal; no suggestion of any instability, lateral or anteroposterior, was detectable.

CASE 3. A. V., an obese female, aged sixty-six years, was admitted to the Hospital on January 31, 1943, after she had slipped and fallen, severely wrenching her left knee. The exact details of her injury were im-

possible to obtain because of language difficulties. On admission, there was marked deformity of the knee joint with obvious lateral and posterior dislocation and considerable swelling. After x-rays were reported confirming the diagnosis, with the additional mention of a small avulsed fragment of the intercondyloid eminence (Fig. 3), reduction was attempted under anaesthesia. Because of the excessive swelling, no medial transverse groove was noted until the gross deformity of the knee was corrected, when it became apparent; and it was evident that full reduction had not been secured. Accordingly, after the knee had been splinted for a few days, she was operated upon, and exactly the same pathological changes were found as in the two previous cases, except for the minor avulsion of the intercondyloid eminence as noted in the roentgenograms and the absence of any meniscus derangement. Immobilization was continued for ten weeks with a change of cast as the swelling subsided. Much chronic swelling persisted for some weeks, but gradually subsided with resumption of activity. On May 30, 1943, five months after operation, knee flexion was to 90 degrees with good anteroposterior and lateral stability. She was walking well without support, and active treatment was discontinued.

She was seen again in September 1944, twenty months after the injury, when she was admitted to the hospital after a cerebrovascular accident. Examination at that time showed that excellent functional recovery had been secured with full flexion of the knee and only minimal lateral instability, probably due to her obesity and excessive weight.

Case 4. C. S., male, aged seventy-five years, was admitted in September 1944, shortly after wrenching his right knee while getting out of an automobile. Examination showed him to be an obese, elderly man who had suffered from hypertensive cardiovascular disease for many years, with one cerebral accident about fifteen years previously from which he had made a good recovery. His heart was enlarged with blowing systolic and aortic murmurs. His blood pressure on admission was 230 systolic, 118 diastolic.

The right knee showed the gross swelling and deformity characteristic of a lateral dislocation of the knee. Roentgenograms confirmed this diagnosis (Fig. 4). No definite transverse groove was noted, probably because of the excessive swelling and obesity. Accordingly, a closed reduction was attempted, but it was unsuccessful; and, as in Case 3, as soon as partial reduction was effected, the transverse depression became obvious.

Operation was advised and performed the next day. Precisely the same pathological changes as in the other three cases were found, and the same procedure was carried out. He stood the operation well, and no cardiac or vascular complications ensued. After simple bed rest, his blood pressure dropped to 148 systolic and 86 diastolic at the time of his discharge from the Hospital on October 17, four weeks after the operation. The cast had been changed in the interim. Three weeks later the cast was removed, and no further support was given except that of an elastic bandage. At this time, he was walking well with crutches and moderate weight-bearing. In spite of his advanced age, motion returned quite rapidly, and on January 14, 1945, four months after the operation, his knee flexion was well beyond a right angle, and he was ready to return to work.

A follow-up examination five years after operation, on August 9, 1949, when he was eighty years of age, showed a functionally perfect knee. He walked without a limp, and went upstairs and downstairs normally. Flexion was as complete as in the opposite knee, quadriceps development was excellent, and lateral and cruciate instability was hard to detect. He rarely used a cane, and then only outdoors, chiefly because he was afraid of stepping into a hole and falling again.

SUMMARY

From a consideration of the above series of cases, the following points may be emphasized:

1. Age apparently was not an important factor in the etiology of this type of dislocation, as the age distribution ranged from seventeen to seventy-five, although it may be noted that three of the four patients were over fifty.

2. The type of trauma seemed not to be a constant factor. In Case 1 and possibly Case 2, the trauma was direct, applied to the lateral side of the knee. In Cases 3 and 4, indirect violence from a slip and fall was responsible.

3. The diagnosis of a traumatic dislocation of the knee is usually obvious at inspection. The diagnosis of an irreducible dislocation, however, depends upon one characteristic sign, — a more or less deep transverse groove or depression along the medial joint line. This sign may be obscured by excessive swelling or obesity; but, even in these cases, it becomes evident when closed reduction is attempted and only partial reduction is secured. Roentgenograms are of no great help, as the hindrance to reduction is a soft-tissue obstruction rather than bone obstruction.

4. Pathological changes were identical in all four cases except for the sprain fracture

of the tip of the intercondyloid eminence found in Case 3, and the loosening or dislocation without gross tearing of the medial meniscus in Case 2.

5. Treatment naturally falls into three categories, — non-operative, operative, and postoperative.

In non-operative treatment, it would appear that attempts at closed reduction should only be made in the absence of a visible transverse groove along the medial joint line and when, consequently, the true diagnosis is in doubt. In this series of cases, all attempts at closed reduction proved to be unsuccessful.

In operative treatment, before actual reduction of the dislocation, the joint should be thoroughly inspected for any additional pathological changes, such as a torn or displaced medial meniscus or loose fracture fragments. Although, in the cases here reported, no fragments were encountered, in another case, the dislocation itself was readily reduced by closed reduction, but check roentgenograms demonstrated a loose fracture fragment in the joint, which required subsequent operative removal.

The problem of postoperative fixation after complete ruptures of the cruciate and lateral ligaments is one about which considerable difference of opinion appears to exist; various periods of immobilization, ranging from four weeks to a year, have been recommended. A somewhat prolonged period might be justified in carrying out conservative treatment of a complete rupture of the medial collateral ligament. In these cases, however, an efficient repair of the collateral ligament (which usually proved to have been avulsed from its attachment rather than ruptured in the middle) has been performed, and the lateral instability of the knee thereby corrected. Admittedly, the cruciate ligaments are also torn, but complete immobilization of the knee from six to ten weeks, if carried out immediately after injury, results in excellent healing and stability of the knee without the necessity of any surgical repair of these ligaments themselves.

It is most important, however, that the plaster fixation be applied with the knee in maximum adduction to relieve the medial collateral ligament of any strain. Inclusion of the foot in some inversion for the first few weeks is also desirable. It is important that the cast be snug-fitting at all times in order to prevent the development of any lateral wobble in the knee during healing. Consequently, one or more changes of the plaster are necessary to counteract any looseness which may result from subsidence of swelling and shrinking of the muscles.

Lastly, it is important to institute setting-up quadriceps exercises as soon as possible after the operation, and to ensure use of the leg muscles by early ambulation, long before the actual removal of the cast. If these simple principles are carried out, an excellent functional result from a severe injury may reasonably be anticipated regardless of the age of the patient.

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A MECHANICAL LEG-LENGTH EQUALIZER FOR USE IN THE OFFICE AND CLINIC

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The correction of scoliosis, pelvic tilt, and inequalities of leg length by raising the short, or apparently short, extremity is a daily procedure in the orthopaedic office or clinic. This is usually done by means of wooden blocks of various thicknesses. The use of these blocks, however, has several disadvantages, — they are likely to get lost and misplaced, weight must be shifted for each change in height, and large corrections are immediately apparent to the patient, and at times produce apprehension.

The device illustrated (Figs. 1 and 2) is designed to minimize these difficulties and to save the time both of the surgeon and of the patient. It consists of two parallel platforms of moderately heavy steel, one fixed and one movable in the vertical plane. The movable platform is raised or lowered by the worm gear of an automobile jack. The over-all range of motion is three inches. For larger corrections, wooden blocks can be placed on the fixed platform.

This device has been particularly helpful in the management of patients with back pain associated with scoliosis and a short lower extremity. The patient stands on the two platforms, facing away from the examiner, and the scoliosis is gradually corrected. At times relief from pain is immediate, since the repeated stimuli associated with stepping on and off a pile of wooden blocks are absent.

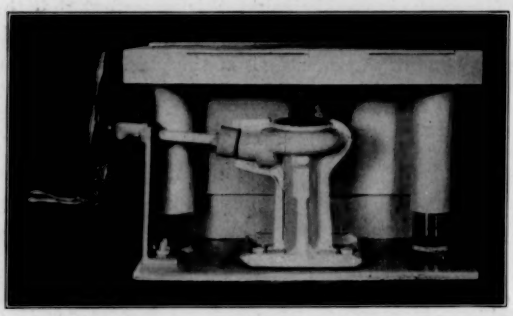

FIG. 1

FIG. 2

DISCUSSION

(Continued from page 778)

We all hope that the end results of Dr. Phemister's bone-graft treatment of avascular necrosis will be as favorable as the early cases suggest. Under these encouraging circumstances, we should agree to a prolonged period of non-weight-bearing.

In this series, traumatic arthritis was present more frequently than avascular necrosis. The challenge presented by traumatic arthritis should not be obscured by the great advances made in the study of avascular necrosis.

ENGELMANN'S DISEASE (PROGRESSIVE DIAPHYSEAL HYPEROSTOSIS)

Report of a Case

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AND J. WARREN WHITE, M.D., HONOLULU, HAWAII

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Engelmann's disease is a rare disorder, characterized by fusiform expansion and hyperostosis of the diaphyses of the long bones, together with malnutrition and underdevelopment. Nine such cases have been reported so far.

Engelmann first called attention to this disease in 1929 when he published "Ein Fall von Osteopathia hyperostotica (sclerotisans) multiplex infantilis". In 1943 Riley and Shwachman reported two cases with almost identical findings and described the condition as "Unusual Osseous Disease with Neurologic Changes". Sear, in 1948, described another case under the title of "Engelmann's Disease". In 1948, Neuhauser, Shwachman, Wittenborg, and Cohen presented a study of two new cases and a follow-up on the two cases previously reported by Riley and Shwachman, under the title "Progressive Diaphyseal Dysplasia". Michaelis reported one case in 1949. Bingold, in 1950, described an additional case and reviewed the seven cases previously reported. Stronge and McDowell contributed the report of the ninth case in 1950.

We feel that the term "Progressive Diaphyseal Hyperostosis" is a more fitting name for this syndrome. Hyperostosis is the term used by Engelmann in his original title and etymologically is a more precise description of the bone changes than is the word dysplasia.

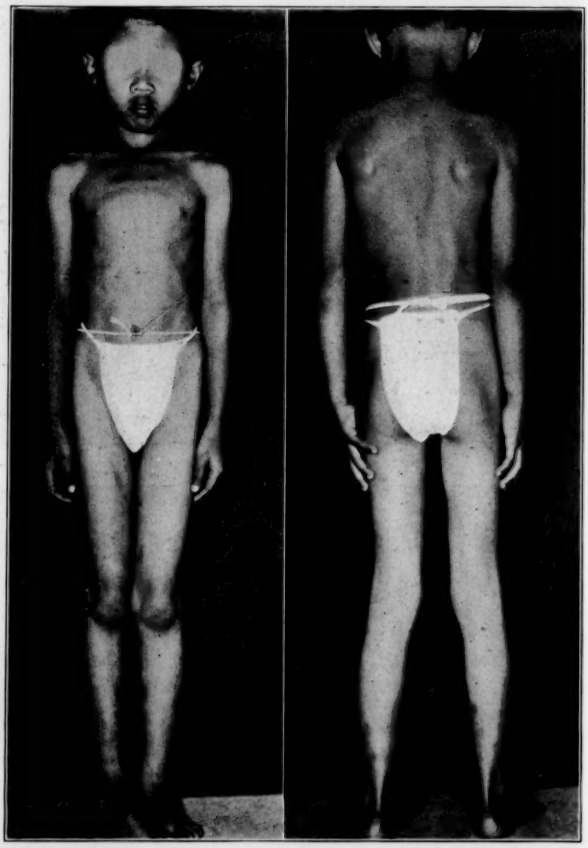

Fig. 1-A Fig. 1-B

Photographs showing anatomical type. Notice the long femora and the underdevelopment of the thigh muscles.

CASE REPORT

The patient, a nine-year-old Filipino boy, has been followed in this Clinic for two years. Presenting symptoms were pain and weakness in the lower extremities of two to three years' duration. His birth and delivery had been normal. He had had no serious illnesses, although in infancy there had been

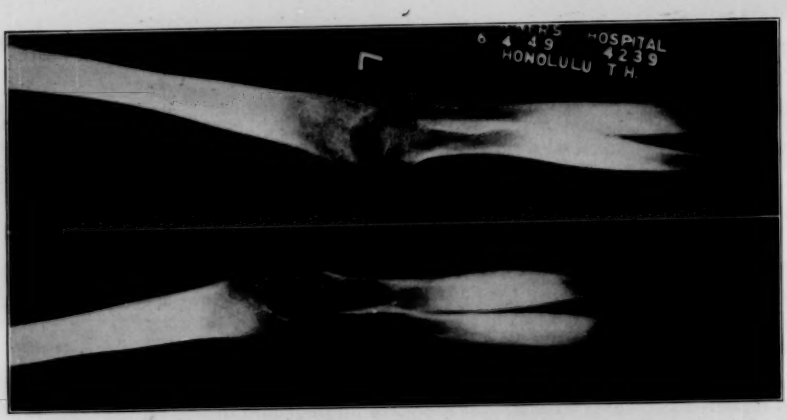

FIG. 2-C

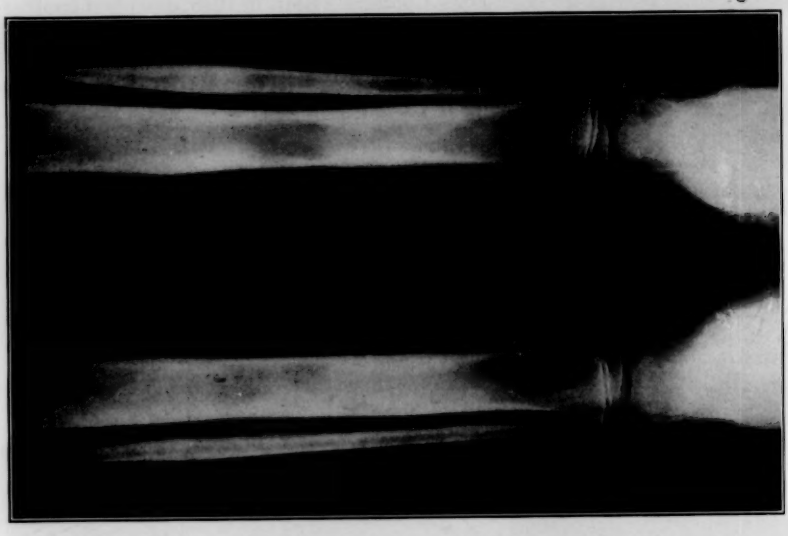

FIG. 2-B

Fusiform enlargement and hyperostosis of diaphyses of long bones.

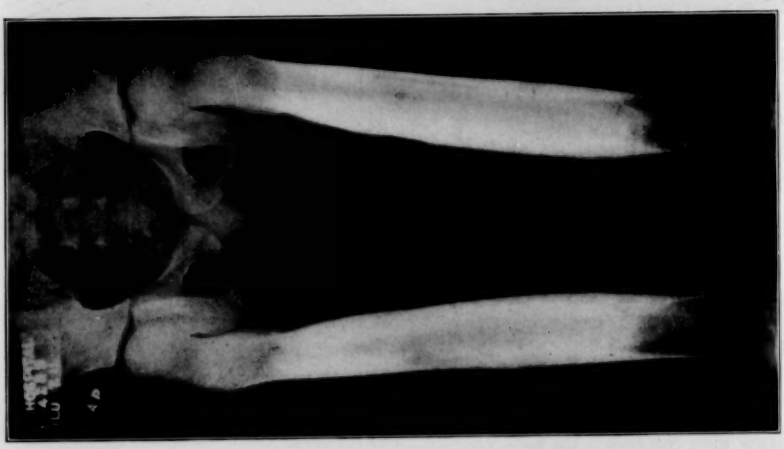

FIG. 2-A

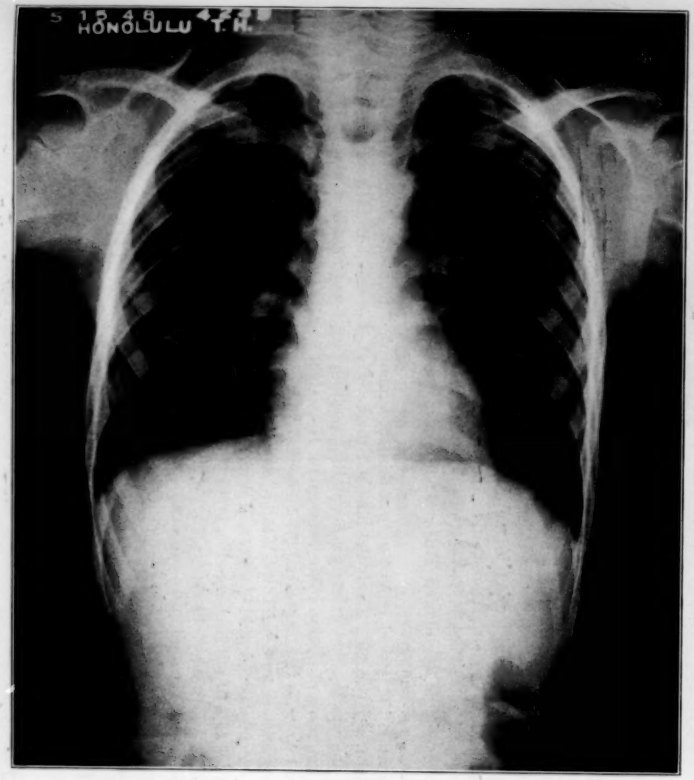

FIG. 3
Normal chest plate, with normal ribs and clavicle.

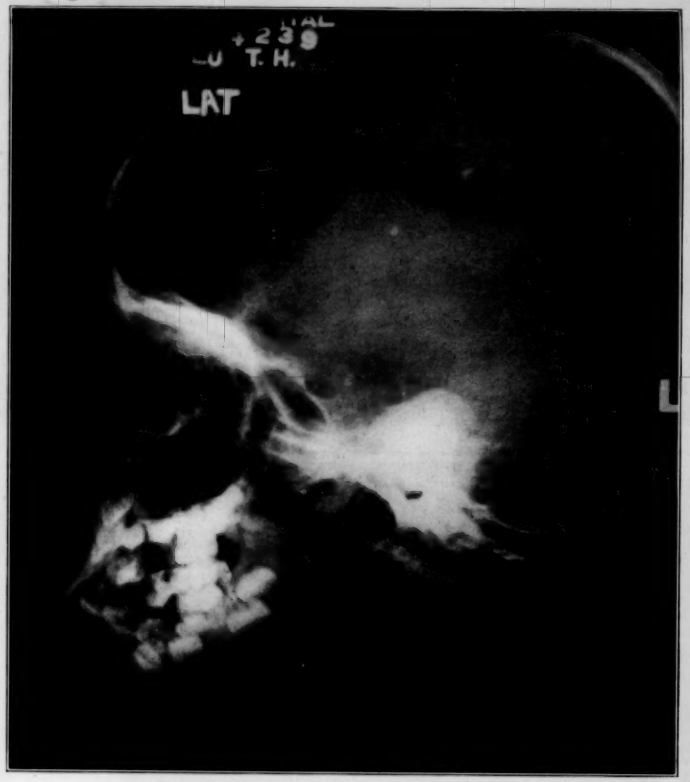

FIG. 4
Showing sclerosis of the petrous portion of the temporal bone.

FIG. 5

Section of cortical bone (× 30), showing enlarged and thickened trabeculae and diminution of osteocytes. (Hemotoxylin and eosin stains.)

FIG. 6

Roentgenogram of femur two years after initial examination. Note progression of hyperostosis.

a series of febrile attacks of unknown etiology. He had always been weak and thin as compared with other children of his age. His pain was described as an ache of moderate severity, which occurred particularly after any physical exertion.

Both parents were living and well. The mother's Wassermann was negative. An older brother was of the same anatomical type as the patient, but on roentgenographic study he proved to have normal bone structure. Some time prior to the initial examination, the family had joined a religious sect which prohibited the eating of any food of animal origin. The diet of the patient, therefore, consisted entirely of raw and cooked vegetables; not even milk was allowed. This was not believed to play a part in the etiology of his illness, but it did later complicate therapy.

On examination the patient proved to be a thin, undernourished boy with marked underdevelopment of the musculature, particularly about the hips and thighs (Figs. 1-A and 1-B). He walked with a wide, waddling gait and was unable to rise from a squatting position because of muscle weakness. There was no tenderness or limitation of motion in the extremities. His weight was 39 pounds, sitting height 25.5 inches, length of lower extremities 24 inches, and total height 47.75 inches.

Laboratory findings were as follows: Wassermann and Kahn tests were negative. Urinalysis was normal; Bence-Jones protein was absent. Mantoux and Schick tests were negative. Blood picture was normal, with the sedimentation rate 21 millimeters per hour (by the Cutler vein method).

Chemical analysis was as follows:

Blood calcium 10.8 milligrams per 100 cubic centimeters;
Phosphorus 3.2 milligrams per 100 cubic centimeters;
Alkaline phosphatase 16.4 Bodansky units;
Acid phosphatase 0.6 Bodansky units;
Plasma cholesterol 89 milligrams per 100 cubic centimeters.

The roentgenographic findings were of the greatest interest. A skeletal survey showed diaphyseal involvement of the long tubular bones bilaterally, consisting of fusiform enlargement and characterized by cortical sclerosis (hyperostosis) interspersed with areas of narrowing. The petrous portions of the temporal bones were sclerotic. The other bones of the skeleton were not involved. Figure 6 is a roentgenogram of the

femur taken two years after the initial examination and shows progression of the process. The films also indicate that the normal layer of subcutaneous fat is practically absent and that the musculature is underdeveloped.

A biopsy of the mid-shaft of the ulna revealed a thickened periosteum and a thickened and sclerotic cortex. Microscopic examination (Fig. 5) showed heavy and hypertrophied trabeculae. There was no evidence of any inflammatory process. Histological diagnosis was benign hypertrophy of bone of undetermined etiology.

DISCUSSION

The clinical and roentgenographic findings in all of the reported cases have been quite similar. The bilateral changes in the diaphyses of the long bones, as well as the malnutrition and underdevelopment, are consistently present. No constant laboratory data of significance have been found. Biopsies have shown diffuse non-specific bone changes. No hereditary influences are yet evident; the etiology is obscure. Treatment has been empirical and generally unsatisfactory. The prognosis of this progressive disease is unknown, since the oldest patient reported is only twenty-eight years of age. The authors feel that a more appropriate term for this syndrome is "progressive diaphyseal hyperostosis".

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OSSEOUS TUBERCULOSIS WITH NEGATIVE TUBERCULIN TEST

REPORT OF A CASE

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Although it is generally accepted that a negative reaction to the tuberculin test precludes the possibility of tuberculosis of bone, exceptions have been noted. Girdlestone states that "in a very ill patient with rapidly progressive disease a negative skin reaction does not exclude tuberculosis of bone". Sanchis-Olmos is of the opinion that a negative reaction may be observed during the first two or three months of the disease. Also, he states that measles induces a negative phase which lasts "two or three months, sometimes longer". He mentions rare instances of "verified osteoarticular tuberculosis observed by various authors (through positive inoculation in the guinea pig, biopsies, and analysis of the pus) in which the reaction to the tuberculin test was repeatedly negative".

A number of authors have reported on the incidence of reactions to the tuberculin test in tuberculosis of bone. Positive reactions were recorded in all of the nineteen cases observed by Howard, Johnston, and Mitchell; in 90.9 per cent. of 121 cases from The Hospital for Joint Diseases, as reported by Blair and Galland; in 92 per cent. of eighty-five cases[1] at the Massachusetts General Hospital and Children's Hospital in Boston; in all

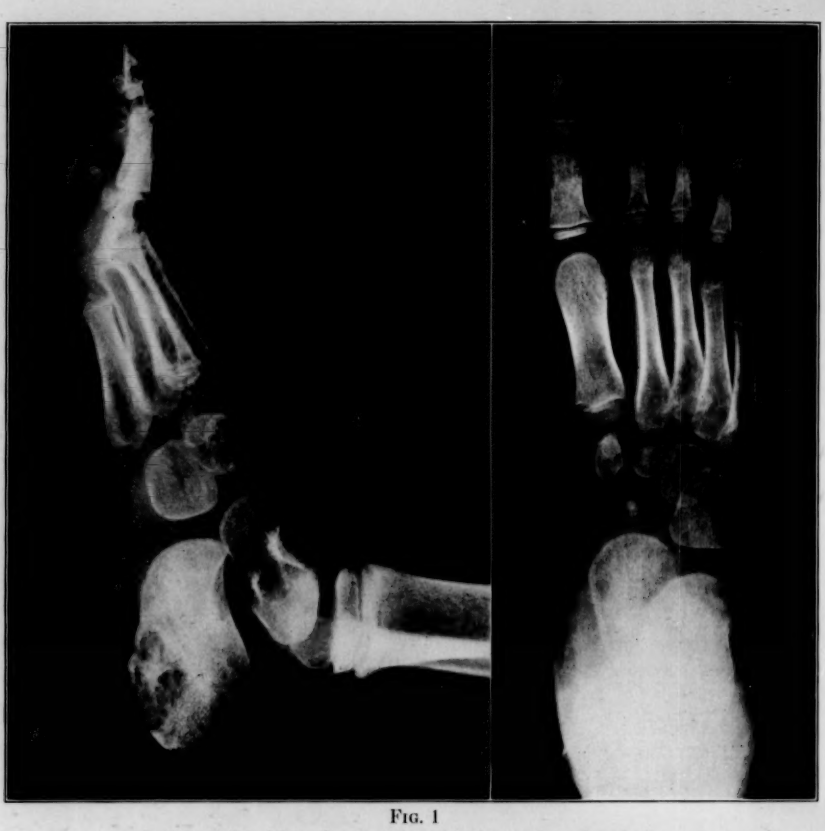

FIG. 1

Defect of the right calcaneus proved to be a tuberculous lesion.

but one of 538 patients[4] at the New York Orthopaedic Hospital; and in thirty-eight of thirty-nine cases of tuberculosis of the spine reported by Chandler and Page.

Discrepancies can be found in the great majority of reported instances of a negative reaction to the tuberculin test in tuberculosis of bone. First, in many of the cases with negative reactions, the question may be raised as to whether or not the diagnosis of tuberculosis was proved by the actual recovery of tubercle bacilli. Second, a false positive reaction may be obtained, on many occasions, by the use of a large dose of tuberculin, thus causing a non-specific reaction.

At the Orthopaedic Hospital, Los Angeles, positive reactions to the tuberculin test were obtained in thirty-two of a total of thirty-three patients with osteo-articular tuberculosis. The case history of the one patient with a negative reaction to the tuberculin test is presented.

This case is of especial interest because the reaction to tuberculin was negative on three separate occasions, the patient was not acutely ill, yet tuberculosis of bone was present.

A two-year-old Negro girl (T.W.) was admitted to the Orthopaedic Hospital on November 18, 1949. Her mother stated that, for the previous five weeks, the child had been "limping on the right leg". There

FIG. 2

Tubercles in the right calcaneus. Acid-fast bacilli were recovered when a guinea pig was injected with material from this area.

was no known previous injury or disease. The mother had noted that the child complained of pain in the arch of the right foot when she was being bathed and also that she usually walked only on the toes of the right foot.

When the child was examined, it was noted that she had an equinus gait, but there was not a fixed equinus deformity when the foot was passively dorsiflexed. There was slight atrophy of the right calf and a slight thickening of the right heel laterally and medially. When the upper extremities were examined later, loss of extension of the right elbow of 20 degrees and flexion limited to 110 degrees were observed. Motion of the left elbow was normal.

Roentgenographic Examination

Roentgenograms were made of the right calcaneus, the chest, and the forearms. The roentgenologist's report is summarized as follows: A mottled area of destruction of the center of the os calcis was seen; there was evidence of minimum soft-tissue and bone reaction about this lesion. There was some peribronchial

infiltration which was essentially normal. In the forearms, some mottling and trabecular markings in the proximal halves of both ulnae were disclosed, and the medullary canal was narrowed. A localized area of destruction was present in the distal end of the left radius.

Tuberculin Tests

Results of tuberculin tests were read by the staff consultant on tuberculosis. The accuracy of the readings cannot be questioned. The Mantoux test with 0.01 milligram of old tuberculin on November 22, 1949, was negative. The test was repeated on November 24, using 0.0005 milligram of purified protein derivative, and again on February 16, 1950, using 0.01 milligram of old tuberculin. On both occasions the reaction was again reported as negative.

The cutaneous reaction to the test for coccidiosis was negative, as was that to the Kline test for syphilis. The sedimentation rate was 16 millimeters in an hour by the Cutler method.

Biopsy

A biopsy of the right calcaneus was performed on January 20, 1950. There was heavy infiltration of small round cells, plasma cells, and mononuclear phagocytes, many with vacuolated cytoplasm. Frequent multinuclear giant cells were seen. Occasional discrete tubercle-like structures of round cells of fibroblastic structure were present; evidence of central caseation could not be found. Several small spicules of bone were necrotic. Special stains failed to reveal evidence of tubercle bacilli.

Material obtained at this biopsy was used for guinea-pig inoculation. On March 20, the animal was sacrificed. Evidence of tuberculosis was present in the lymph glands, the liver, the spleen, the lungs, and the tracheobronchial lymph nodes. Acid-fast bacilli were demonstrated in these lesions.

Another biopsy was performed on April 10. By this time the patient had been given streptomycin and para-aminosalicylic acid. A guinea pig, injected with some of the biopsy material, was sacrificed eight weeks after the biopsy. Acid-fast bacilli again were demonstrated.

COMMENT

There can be no doubt of the presence of tuberculosis in this case. The recovery of tubercle bacilli from the guinea pig on two separate occasions obviates the chance for any technical error in the procedure. The histological appearance of the involved bone was confirmatory.

The patient was not gravely ill at any time, so that the negative reactions to tuberculin cannot be attributed to extreme severity of the tuberculous disease. There was not any intercurrent exanthematous disease to mask the tuberculin test.

NOTE: Acknowledgment is made to Dr. Percy K. Telford and Dr. Ralph Miller for their assistance in the preparation of this report.

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SOME CURRENT CONCEPTS ON THE MECHANISM OF CALCIFICATION*

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Bones are living tissues, not inert structures; new bone is constantly being made and old bone resorbed [34]. The inherent capacity within a cell to make bone has been called by McLean [36] "osteogenetic potency". Environmental factors of many types cause cells with such potentials to elaborate a matrix in which are embedded the lime salts which provide the skeleton with its rigidity. The present communication will attempt to review and to correlate certain clinical and experimental data on the mechanisms which bring about calcification. It will become apparent that the major result of this effort is to highlight the gaps at present existing in our knowledge of calcium and phosphorus metabolism.

On The Nature and Function of Bone Mineral

The rigid scaffolding of bone is composed of minerals, and though not a pure chemical or any single chemical individual, there is normally a relative constancy of composition that is striking. From the physical chemists and crystallographers, we learn that tertiary calcium phosphate of some kind is the main crystal structure and that the basic lattice is of an apatite nature [24]. Analysis of bone salt discloses—in addition to calcium and phosphate—the presence of other constituents, among which are sodium, magnesium, citrate, and carbonate. It seems likely that bone salt is an hydroxy-apatite and that carbonate, sodium, magnesium, and citrate are resident on the *surfaces* of the crystals and are not part of the crystal molecules [24, 25, 26]. This may prove to be an extremely important new concept in offering a partial explanation for the ready availability of skeletal calcium in times of need,—a subject which will be discussed later.

Calcium Homeostasis and Transport

In order for the constant turnover to take place, the principal minerals, calcium and phosphorus, must be brought to and from the bones. Such transport is accomplished by the blood stream, extracellular fluids, and lymph. Calcium is normally present in the serum in concentration of 9.5 milligrams to 11.5 milligrams per 100 cubic centimeters, but about half of this calcium is "bound" to protein and, hence, is not freely diffusible across the normal capillary membrane. Thus the fluid actually bathing the cells contains presumably about 5 milligrams calcium per 100 cubic centimeters of serum. The phosphorus of the serum is almost all inorganic phosphate, and this is completely diffusible. We have no simple and accurate way of measuring the diffusible serum calcium, but McLean and Hastings have devised a chart from which one may compute the diffusible calcium when the total calcium and total protein values of the serum are known [37]. However, the albumins, gram for gram, probably "bind" slightly more calcium than do the globulins, which are larger molecules. Thus a pathological serum with high total protein, most of which is globulin, might bind only as much calcium as would the protein of a normal serum with albumin-globulin ratio of 2:1. An example of this is provided by a recent patient with myeloma, whose total serum calcium was 12 milligrams per hundred cubic centimeters, total serum protein 12 grams per hundred cubic centimeters, of which the globulin was 10.5 grams. When tested, the diffusible calcium proved to be in the normal range [27], but on the McLean-Hastings's diagram the diffusible calcium would be read as low. Thus, in certain pathological sera, the diagram may be misleading.

The calcium content of the serum is dependent on the balance between how much enters and how much leaves the system. Calcium can enter from only two sources: from the intestine, that is, absorption of ingested calcium, or resorption from the skeletal stores; for 99 per cent. of the calcium within the body resides in the bones and teeth [2]. Calcium may leave the system by way of the urine, in the stools (being derived from intestinal juice calcium which may remain unabsorbed), or it may go into the bones.

Factors governing absorption from the gut are but vaguely understood. It is not known in what state or how calcium crosses the intestinal membranes, but evidence favors the opinion that the absorption occurs in the upper intestinal tract, and that the acidity of the medium (intestinal juices) favors absorption. The presence of other substances for which calcium has relative affinity—for example, an excess of phosphate [14, 49] (or, of course, oxalate)—reduces calcium absorption. There is reason to believe † that the normal adult individual absorbs between 100 and 200 milligrams per day [2]. It is probable that somewhat greater quantities may be absorbed if large moieties of calcium are ingested as chloride, gluconate, or lactate salts in the absence of equivalent quantities of phosphorus [29]. Vitamin D appears to be a requisite for optimum

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† It seems logical to suppose that the *normal* adult is in calcium equilibrium, that is, that what he takes in equals that which he puts out. Therefore, absorbed calcium probably equals that which is excreted in the urine, which rarely is more than 150 milligrams in twenty-four hours, even though he may drink a quart or more of milk.

calcium absorption [46], for in vitamin-D deficiency very little is absorbed; and one of the first detectable changes after the administration of the vitamin is a rise in calcium absorption [5, 9].

Since so small a proportion of the ingested calcium of our high-calcium American diets gains access to the transport system in the normal adult, the bulk of ingested calcium appears in the stools. There is no evidence to our knowledge that the large intestine secretes calcium. However, there are many instances when the amount of calcium in the stool is greater than the quantity ingested. The combined volume of the various digestive juices has been estimated to be more than eight liters per day [18]; and since these juices are but modified serum transudates, they would contain nearly one-half a gram of calcium. Should this calcium not be re-absorbed, due to the presence of excess calcium precipitors such as phosphate, fatty acids as in steatorrhoeas, or because of any diarrhoeal state where intestinal motility would be very rapid, the losses of calcium from the body by this channel might be very great indeed.

Factors governing excretion of calcium by the normal kidneys are but vaguely known. If the glomerular filtrate (which forms normally at the rate of 100 cubic centimeters per minute or more) contains the diffusible fraction of the serum, as seems likely, there would then be presented to the tubules approximately 9 grams of calcium per day. Since only 100 milligrams of calcium appear in the urine, more than 99 per cent. must be resorbed. Thus very minor variations either in the amount presented or the relative quantity resorbed could result in large quantitative differences in the urinary content, and the causative situation would be difficult to discern. Acidosis [40], the hormonal abnormality of Cushing's syndrome [1], disuse atrophy of the skeleton [11, 29], thyrotoxicosis [3], and urinary-tract infection [2, 43] are some of the conditions associated with hypercalcinuria, usually without any concomitant elevation of the total serum-calcium concentration.* In experimental hyperparathyroidism, urinary calcium may increase 100 per cent. without appreciable change in the serum-calcium level [2]. Many patients with a history of urinary lithiasis have been found to excrete excessive quantities of calcium in the urine without other abnormal findings [15]. In all of these conditions, the *diffusible* fraction of the serum calcium may be increased, or there may be some change resulting from the disease which lessens tubular resorption. Conversely, during the course of development of vitamin-D deficiency, calcium diminishes and finally disappears from the urine, before total serum-calcium concentration falls appreciably [9].

All these factors at play, poorly understood at present, some tending to raise, others tending to lower the concentration of calcium in the circulating fluids, must be regulated by an extraordinarily delicate mechanism of homeostasis. For it is rare to find patients with either hypercalcaemia or hypocalcaemia.

To return to the skeleton, whatever may be its true chemical and physical nature, the clinician has long been aware that some of the calcium present in the skeletal tissues is readily available for mobilization in time of need. Starvation does not quickly result in a fall of serum-calcium concentration, despite the fact that calcium continues to be discharged in the urine and faeces [12,51]. Even when a deficient diet is combined with lactation, where the demand for calcium is obviously great, the calcium content of neither the milk nor the serum usually shows an appreciable fall [35]. In rats the serum-calcium concentration does fall after prolonged low calcium intake [8], but Kramer and Howland [32] found that animals could be carried on such diets for succeeding generations before the fall reached extremely low levels. Some of the ion-exchange resins, recently introduced into clinical medicine for purposes of dehydrating oedematous persons, prevent absorption of calcium as well as other cations, yet the serum-calcium concentration is usually maintained for several weeks [33]. An individual of average size has less than one gram of calcium in the blood and extracellular fluids of his body. In times of great calcium loss, it is readily apparent that tetany would quickly result if the bones did not furnish calcium; there is no other source.

In this connection, an unpublished experiment of Hastings and Huggins [22] furnishes a graphic example. These investigators removed from dogs one half of their blood volume every ten minutes, replacing it with blood from which the calcium had been removed with lead phosphate. Hastings calculated that in three hours of such treatment, there was removed four times the amount of calcium originally present in the extracellular fluids of the dog; and though the serum calcium fell, the observers never saw active tetany in the animals. Furthermore, the serum-calcium concentration returned to normal a few hours after the experiment ended. There are certain situations, however, in which the bones seem incapable of supporting the serum calcium. In some patients with steatorrhoea, even with bones which appear to be of normal density by roentgenogram, hypocalcaemic tetany is a constant problem. Other patients with extreme skeletal rarefaction maintain normal serum-calcium levels [28]. This seeming paradox has puzzled us. It has been said that Puerto Ricans rarely have rickets [13] and that people with sprue rarely have tetany. We have observed a patient with steatorrhoea whose serum calcium rose and whose tetany cleared when daily exposure to Baltimore's summer sunlight was provided.† Copp's experiments with radio-active calcium (Ca^{45}) may be pertinent in this connection. He found that in young rachitic animals (made rachitic with very low-phosphorus diets *but with added vitamin D*), the skeleton took up the radio-active calcium just as rapidly as did the normal young growing rats, but that it was rapidly excreted again, mostly in the urine [10]. It seemed that Copp's rachitic rats could take up the cal-

* It should be recalled that the methods for determining the total serum calcium in common use are sensitive only to 0.2 milligrams per 100 cubic centimeters.

† This patient was seen with Dr. George W. Thorn.

cium but could not incorporate it in the apatite lattice; and thus they were unable to hold it. The role of vitamin D in influencing the exchangeability of calcium with skeletal tissues deserves further study.

The parathyroids must also be a dominant factor in the ability of bones to provide calcium to the extracellular fluids in time of need. In many animals, including man, removal of these glands is followed by a precipitous fall in serum-calcium concentration to tetanic levels. Partial restoration of the serum calcium by means of intravenously injected or orally administered calcium salts is of but transient benefit.

Hastings [23] noted that when fresh bone was shaken with serum, the calcium of the serum decreased even within ten minutes, though the phosphate remained unaltered. The decrease in calcium equalled the loss of carbonate, so that calcium carbonate was being removed and not calcium phosphate.

All of the above would lead one to believe that the bones normally act as an adjustable compartment for calcium storage or release in times of calcium stress.

Mechanisms Involved in Deposition of Lime Salts, Extracellular Environment, Enzymes, and Matrix

For normal deposition of lime salts to occur in bone and cartilage, there is required an adequate concentration of calcium and phosphorus in the environment—that is, the extracellular fluid. Suboptimum concentration of these elements results in rickets or osteomalacia. By suitable dietary measures, rickets may be produced in growing animals from too low a concentration of either serum calcium or phosphorus [30]. The clinical pattern of rickets and the histological picture of uncalcified cartilage matrix, poor and irregular invasion of these areas by capillaries, and the uncalcified osteoid borders of the trabeculae of the bones are well known [38]. Proof that the fault here lies at least partially in the chemical environment is afforded by the fact that the cartilage will calcify *in vitro* when exposed to the sera of normal infants [47].

The observation that there is an accumulation of glycogen in the maturing cartilage cells adjacent to the area where calcification will occur, and the discovery of the presence of phosphatase [42] and phosphorylase [20] in the epiphyseal cartilage induced extensive investigation of these substances in relation to the process of calcification but without identification of their exact roles as yet. At a recent conference on the metabolism of bone, Gutman summarized our present knowledge of these mechanisms as follows: "It is quite evident that no system of calcification yet proposed takes into sufficient account the important differences disclosed by histological and histochemical study in endochondral calcification, endosteal calcification and periosteal calcification, nor has any satisfactory mechanism been suggested to explain the complex and diverse actions of the various hormones and vitamins" [19].

Some years ago the possibility that certain properties of the matrix might play an important role in the mechanism of calcification seemed worthy of study. Histologists have long insisted that under the microscope one never sees resorption of lime salt without the concomitant disappearance of the matrix [30]. Follis [17] has pointed out that wide osteoid surfaces (uncalcified bone matrix) are commonly seen in patients dying from chronic renal insufficiency, despite the fact that such patients have high serum phosphorus concentration and generally but little lowering of the serum calcium. Likewise in animals poisoned by high doses of vitamin D, when both calcium and phosphorus in the serum are elevated, uncalcified osteoid surfaces are frequently met [21, 16]. The environment *seemed* suitable for calcification; *perhaps the matrix was not.* These considerations led to the hypothesis that there may be some characteristic property of the normal bone and cartilage matrices which, in a reasonable environment, *require* deposition of lime salt and may actually determine the nature of the apatite complex to be laid down. Some of the studies resulting from this concept, though in a preliminary stage, have fortified the impression that more knowledge of the nature and evolution of the matrix is urgently needed.

By means of two well known histochemical techniques and fresh-tissue slices, the conclusion was reached that there are present (as a group) acid mucopolysaccharides in the matrix of both bone and cartilage [34]. Metachromasia, a purple color, depends upon an alteration in the light absorption of toluidine blue when this dye is attached to highly polymerized compounds. The red color of the Schiff reagent (leucofuchsin) depends upon the formation of ketone radicals from adjacent hydroxyl groups. It was felt that by the use of these two histochemical methods on formalin-fixed and frozen fresh tissues, when the tissues stained positively *by both techniques*, the presence of acid mucopolysaccharides could be identified with assurance. The various known substances which can interfere with the specificity of either method alone do not react with both [45].

Uncalcified cartilage is metachromatic; calcified cartilage is not. Sylvén had previously interpreted this fact to mean that metachromatic staining material of the cartilage matrix is removed during the conversion to the calcified state. However, when calcified cartilage is treated with 1 per cent. nitric acid for five minutes, it becomes highly metachromatic [34]. This is interpreted to mean that acidification has removed calcium molecules from acid radicals, thereby freeing places on which toluidine blue may attach. Thus the metachromatic staining material of the matrix had *not* disappeared when the lime salt deposition occurred. Both uncalcified and calcified cartilage matrix stain pink with the periodate fuchsin, but acidification is part of this technique (sulphurous acid fuchsin). Rubin feels that the polysaccharide thus identified in *cartilage* matrix is almost certainly chondroitin sulphuric acid, long known to be present in cartilage in high concentration [45].

In bone, which differs in many respects from cartilage, a similar situation with regard to these histo-

chemical reactions was found. Osteoid, that is uncalcified, bone is both metachromatic and stains positively with periodic acid fuchsin. Calcified bone is not metachromatic, but becomes so after gentle treatment with acid [45]. Thus there is polysaccharide in calcified bone, too.

Rubin [44] next noted that in the transitional zone of cartilage, *prior* to calcification, there is seen a characteristic sharpening and intensification of both these staining reactions. The same intensification appears in certain structures about to become bone,—namely, in tendons and ligaments at exactly the places which will be converted from fibrous membrane to calcified bone. Furthermore, the areas which have most recently calcified stain most intensely with periodic acid fuchsin. These observations are interpreted to mean that in the region about to calcify there is increased affinity for cations (toluidine blue) and that there are also more adjacent hydroxyl radicals which are alterable to ketone groups by periodic acid. Either *more mucopolysaccharide* (it could be condensed and hence more concentrated) is present at such places just prior to calcification, or its chemical state has altered in some way—possibly by depolymerization—to make many more molecules.

An opportunity was afforded to study the tissues obtained at biopsy from a patient with generalized calcinosis. It was found that the calcified lesions contained an organic material metachromatic with toluidine blue and strongly positive with the periodic fuchsin technique. The formed elements resembling crystals failed to stain with toluidine blue (just as does calcified bone or cartilage). With the von Kossa technique (the black in such preparations presumably identifying areas previously occupied by calcium) both the amorphous and crystal-like components of the smears were positive. Heating a fresh smear over a flame produced first charring, then a white ash. The ash failed to stain with toluidine blue or leuco-fuchsin, but the ashing process produced no change in the microscopic appearance of the material as compared with the unstained smears. Decalcification of the original material with 1 per cent. nitric acid produced no recognizable change of shape of the material, but the consistency altered from one of gritty hardness to gelatin-like softness. The decalcified structure was *metachromatic* and remained positive with the periodic acid fuchsin staining. The conclusion was reached that the calcium salt of calcinosis nodules, previously identified as calcium carbonate and calcium phosphate, essentially similar to that of normal bone [4], is deposited in an organic matrix, and that this matrix contains a mucopolysaccharide [45].

Other types of human calcified tissues were next examined; and it was found that arteriosclerotic placques, calcified pericarditis, and dental tartar all have basic matrices with these same staining properties. Calcific renal calculi, with the exception of oxalate stones (this exception having been predicted by Rubin and Levine), were likewise found to contain matrix with similar staining properties. Bevelander [7], studying the formation of mollusc shells (calcium carbonate), noted a matrix that stained positively to periodic fuchsin prior to calcification and that this staining reaction became progressively more intense in the transition from the uncalcified to the calcified state [6]. These observations suggest that certain tissues, under appropriate stimuli, elaborate a mucopolysaccharide-containing matrix which, in the *normal* extracellular environment, may predetermine the laying down of lime salts in a characteristic pattern. A variety of abnormalities could interfere with the final calcified product—for example, general nutritive failure would take away the building blocks necessary for fibroblastic proliferation and for matrix formation; there might occur specific deficiencies which would block a single enzyme system or the multiple enzyme systems necessary for full maturation of the calcifiable matrix; or the environment might be reduced in mineral content so as to render calcification impossible even with a perfect matrix present.

The mechanism of production of vicarious calcification—that is, deposition of calcium salts in areas not normally calcified—is a subject worthy of some attention. In certain types of degenerating and necrotic placques, there seems to be a *local* stimulus to lay down a calcifiable matrix. Likewise in the disease calcinosis there appears to be some alteration in the fibroblasts of the subcutaneous, fascial, and ligamentous tissues, resulting in elaboration of an abnormal matrix which calcifies in *normal* extracellular fluid. The vicarious calcification seen *when there is hypercalcaemia present*, however, seems to be differently initiated. Here the excessive concentration of calcium appears to play the important role. One place where vicarious calcification due to hypercalcaemia is easy to observe is in the conjunctival tissue of the eye [50]. We have seen this phenomenon in patients whose serum calcium was elevated from a variety of diseases—hyperthyroidism, poisoning from vitamin D, sarcoidosis, multiple myeloma, general carcinomatosis, and cancer of the lung without detectable skeletal involvement. A particularly remarkable feature of this hypercalcaemic calcification is its reversibility; when the cause of the hypercalcaemia can be removed, the eye lesions have been seen to disappear completely [50]. The actual nature of the lime salts laid down in such lesions is unknown; they merit study by chemical analysis and by x-ray diffraction. Whether these deposits are resorbed by enzymatic activity of fibroblasts, as is generally conceded to be the case with bone resorption, is not known. It would be of the greatest importance to know whether hypercalcaemia *per se* alters cells in such a way that they now lay down calcifiable matrix (where ordinarily they do not) and to resorb such when the stimulus of hypercalcaemia is removed; or whether the matrix remains unchanged but simply happens to be of such a nature that it will calcify in a hypercalcaemic environment.

The scope of this paper renders it impossible to discuss a variety of other agents and mechanisms which may participate in calcification. The factors in serum phosphorus homeostasis are obviously of great importance and have been only briefly mentioned. Phosphorus takes part in so many metabolic processes that

its skeletal participation is difficult to identify from balance experiments. The relation of the sex hormones to skeletal metabolism in man is as yet poorly understood. The spectacular effects of estrogens on the calcium metabolism of birds and certain amphibia appear to have no counterpart in the human. The role of the blood supply in deposition and resorption of skeletal tissues needs further study; the observation of Pearse and Morton that venous ligation speeds fracture healing has never been adequately explained. The mechanism whereby occurs the rapid rarefaction of bones put at rest or with severed nerve supply, and the osteolysis resulting from acidosis [31] are not understood.

There are thus many unanswered problems in this highly complex field of calcium metabolism. It appears to be a fertile and profitable one for future investigation.

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THE EARLY TREATMENT OF HAND INJURIES

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The outlook for the injured hand, as to whether it is doomed to disability or will regain useful function, depends primarily on the first aid and early definitive treatment rather than upon the care during convalescence. We should be guided, therefore, in this early treatment by an understanding of the causes of hand disabilities, so that we may select methods which lead to the restoration of function rather than those which will result in crippling. Our appraisal of the methods of early treatment must be factual and based on the examination and reconstruction of many injured hands, so that we may correlate the outcome with the method of early treatment used.

Let us therefore attack the problem backward, as it were, by starting with a study of the results and then checking these with the early treatment. This method of studying in retrospect may be putting the cart before the horse, but hindthought may lead to forethought.

Types of Crippling

The hand is such a beautifully and accurately constructed organ that it is readily wrecked by trauma and the results of trauma. When both prehension and sensation are lost, there is complete crippling. Prehension depends upon the ability of the hand to assume the position of function and upon extension and flexion of the digits for grasp. Sensation is dependent upon the nerve supply.

The common types of crippling found are (1) stiffening in the position of non-function, (2) flexion contractures, (3) skeletal malalignment, (4) loss of motion and sensation from tendon and nerve injuries, (5) ischaemic contracture, and (6) trophic disorders. Each of these will be discussed in order.

The most prevalent crippling results from *stiffening of joints* in such a *position of non-function* that the digits cannot be brought into opposition to each other. The usual position of deformity in which the hand joints stiffen is one of non-function. The wrist is flexed and pronated. The proximal finger joints are straight or hyperextended, the arches of the hand are flattened or reversed, and the thumb is at the side and displaced backward. The distal two finger joints are stiffened either in the claw position or straight. The little motion still present in the hand is useless since the digits cannot be opposed to each other or to the palm, and prehension is therefore lost. Hand joints stiffen on slight provocation. They are so accurately fitted together that, whenever their ligaments become shortened and thickened, motion is diminished or absent.

When such a deformity is extreme, the hand is congealed, all of its tissues being adherent. When due to severe crushing, multiple fractures, or infection, it may be reduced to an immobile insensitive club. Such a hand has very poor nutrition due to oedema and lessened blood, lymph, and nerve supply.

Flexion contractures are frequent sequelae of wounds, infections, and burns. They are due to loss of tissue and contracture of scar. Commonly the wrist is drawn into flexion and the digits into the palm. Contractures may also be on the dorsal or lateral aspects. Flexion contractures may be postural from holding the limb in a faulty position until it becomes fixed. Thus the hand, wrist, and elbow may be fixed in deformity or the shoulder cannot be abducted.

Skeletal malalignment from malunion of fractures or unreduced dislocations upsets the mechanics of the joints and tendons, and the nice muscle balance which normally holds the hand in the position of function. Thus an angulation in the course of a limb upsets this balance, causing deformities from the point of angulation distally. Angulation may thus rob a digit of flexion or extension, or may alter its function. Projecting bone ends may cause adhesions to tendons, stopping motion. Errors of rotation cause fingers to cross or diverge on flexion.

Loss of motion may be due to inability to actively flex or extend because of nerve, muscle, or tendon injury or to hindrance of passive flexion or extension due to contraction, shortening, or adhesions in and about joints, capsules, tendons, or muscles. Sensory loss may be from nerve injury or lessened vascularity.

From injuries to the brachial plexus, arm nerves, and main vessels, a hand may also be crippled beyond use. There may be atrophy, fibrosis, poor nutrition, and stiffening in the position of non-function with loss of motion and sensation. Hands partially paralyzed show deformity of wrist and digits from muscle imbalance.

Ischaemic contracture of the Volkmann type results in lowered nutrition, associated with impaired blood, lymph, and nerve supply and produces shortening and fibrosis of the muscles in the forearm. The local type of ischaemic contracture in the hand results in fibrous contractures of the intrinsic muscles. The proximal finger joints are then held flexed and the distal two finger joints straight. The thumb is flexed and adducted into the palm, the hand assuming the position taken when entering a sleeve. The fingers are then unable to open for grasp.

Trophic disorders consist of Sudeck's atrophy, causalgia, and various other vasomotor aberrations result-

ing in lowered nutrition, pain, lessened motion, and fixation in poor position. Long-continued pain, whether the result of trauma or of instability of the vasomotor system, so inhibits motion that these dystrophies may result.

Thus may be summarized the usual types of crippling found. It is important that we understand how these types of crippling are produced and how they can be prevented. Prevention lies in the selection of proper methods of early treatment and in avoiding subsequently the pitfalls that lead to crippling.

Production and Prevention of Crippling

Stiffening in the Position of Non-Function

This most prevalent type of crippling is due to three main factors,—swelling, immobilization, and allowing the hand to remain in the position of non-function. When this vicious triumvirate is allowed to persist, all tissues, not only the movable parts, but also the cells themselves, become glued together by fibrin which precipitates from the protein-rich oedema fluid. Soon blood vessels and connective tissue grow in and the part becomes organized and congealed. Joints and tendons are especially affected. Their sliding surfaces and folds seal together, and the ligaments of these accurately fitting joints become so short and thick that the joints cannot move.

Factor of Immobility

The hand which is swollen and motionless becomes stiff. Hands need mobility to thrive. Even without swelling, they stiffen if kept immobilized too long. Activity of the parts pumps away the stagnant oedema fluids, thus breaking the vicious circle. Prevention of swelling and immobility is a "must" in the treatment of hands. It should be always uppermost in the surgeon's mind when treating wounds, fractures, or infections. The fractured part must be immobilized, but the remainder of the hand should be kept moving. To splint the whole hand, as over a roll of bandage or a ball, prevents the uninjured digits from moving. An infected or burned part must be immobilized, but movement should be started as soon as the acute stage is over. Plaster casts and splints should not include any joint which does not specifically need immobilization and should not be left on any longer than is necessary.

Factor of Position of Non-Function

Why do most injured or paralyzed hands stiffen in the position of non-function? Normally, due to the nice balance of the long flexors, long extensors, and the intrinsic muscles, the hand assumes the position of function as in grasping a ball. The wrist is dorsiflexed about 30 degrees, and the proximal and other finger joints are in moderate flexion. The metacarpals form an arch, and the thumb is in moderate opposition.

When the hand is sick, it is held with the wrist flexed or dropped to fit around the curve of the body as for protection. This flexing of the wrist tightens the extensor tendons, thus cocking back the proximal finger joints, drawing the thumb to the side and back, and flattening the metacarpal arch. When the fingers and thumb are cocked back, the long flexors automatically draw the distal joints into flexion, thus completing the position of non-function. In the sick hand, the muscles shorten, thus accentuating the effect of posture on the muscle balance. The muscles are still in balance, but the position is that of non-function and the digits are useless for prehension.

On analysis it is seen that the wrist is the key joint of the hand, and the proximal finger joints the key joints of the fingers. When the wrist is dorsiflexed, the hand assumes the position of function. When the metacarpophalangeal joints are flexed, the fingers "unclaw". The position of non-function is preventable by proper immobilization of these two key joints,—that is, by keeping the wrist in moderate dorsiflexion and the metacarpophalangeal joints in moderate flexion. When the wrist is dorsiflexed, the metacarpophalangeal joints will flex and the thumb will oppose. If deformities are already present, these should be corrected by elastic splinting.

In the position of non-function, the hand is useless, for the digits cannot work against each other. As soon as the joints are elastically drawn around to the position of function, what little motion is present will be useful, for objects may be picked up. The hand will then be used and, as the result of use, it will improve.

If the wrong position is already present, the two key joints should be corrected by spring or elastic splints. A cock-up splint may be used for the wrist either with an extension to flex the proximal finger joints or in conjunction with a knuckle-bender splint.

When casts are applied, the wrist should be dorsiflexed, not straight or flexed, and the cast should end at the distal flexion crease in the palm, not the plica, to allow full flexion of the proximal finger joints. Except for some specific purpose, it should never extend over the fingers,—that is, past the distal flexion crease in the palm; and it should be cut out over the thenar eminence for free opposition of the thumb.

Infection

Infection is a great wrecker of hands. It is accompanied by swelling and immobility and leads to stiffening in the position of non-function if not prevented. It may also result in the sloughing of tendons, muscles, and nerves, as well as osteomyelitis, joint destruction, and finally flexion contracture.

The prevention of these is by operating on the wound early—the earlier the better. This may be done in a few selected wounds as late as twenty-four hours after injury but never later. Preferably it should be done in from one to eight hours after the injury. The wound should be debrided and any loose fragments of bone removed. It is thus converted into a clean wound and is closed against further infection from without. Most wounds are contaminated with rather non-virulent germs and heal primarily if given the opportunity.

Secondary infection results from mouth spray and contamination from human sources, due to lack of asepsis. Masks, gowns, and adequate operating-room facilities should be used in the early treatment of wounds. Débridement and surgical repair should be done in a bloodless field by using a pneumatic tourniquet. Finally a voluminous fluff pressure dressing should be applied to control swelling and hemorrhage.

Wounds should be closed primarily, if possible, by covering over all vulnerable tissue which cannot live when exposed. The patient is thus spared osteomyelitis, infected joints, sloughing tendons, muscles, and nerves, with resulting contractures and crippling.

Cover may be obtained as follows: The wound may be closed by suture, using a relaxing incision if necessary or, if there is a good bed, by skin-grafting. A skin flap from the adjoining area may be swung to cover the vulnerable parts and a skin graft used to cover the area so denuded. Sometimes by filleting a damaged finger, its skin can be laid over the wound. If these methods are not available, an immediate abdominal pedicle of skin may be applied. Thanks to antibiotics, this is now possible unless the wound is too crushed and dirty or results from explosives. Even in these, after débridement only, the vulnerable parts may be covered over and the wound closed secondarily by a pedicle in five to ten days. When wounds are promptly closed, stiffness of the hand is avoided. If a wound in the hand is left open for long or if the undersurface of the pedicle is left raw, stiffening results.

Flexion contracture results from infected wounds which remain open or may follow burns. Some contractures are due to the position in which the hands are immobilized and some are from ischaemic contracture of muscles. Infection should be avoided or, barring this, terminated promptly, and wounds should be closed as early as possible. Contracting tissue is the last stage of granulation; this is particularly true of burns. It is the deep white layer which is the contracted scar from the granulations, and it is this which shrinks, drawing the limb into deformities. Therefore, a burn should not only be skin-grafted early, on or about the eighteenth day or sooner, but the bed of the granulations should be first scraped off with the back of a scalpel. This is done, using a tourniquet, and after the larger vessels have been ligated, a pressure dressing is applied for hemostasis. Pressure dressings in burns keep the granulations down and radical early treatment prevents deformities. Contractures from infections with sloughing will need later replacement by pedicle skin grafts.

A frequent postural deformity following hand injuries is lack of ability to raise the arm at the shoulder. This deformity is due to keeping the arm constantly at the side for two or three months, until the muscles and ligaments about the joint have contracted. Prevention is by early recognition and raising the arm frequently. A cure may be effected by gradually stretching the arm up in abduction or using a rope and overhead pulley, each arm drawing the other up. Many postural deformities result from splints or casts which hold the hand flat with the thumb at the side, and from casts which are prolonged over the fingers so that their proximal joints cannot flex. Here the collateral ligaments become so short and thick that flexion is impossible.

Skeletal malalignment should be recognized and corrected early, avoiding the necessity of correction by osteotomy later. Not much traction is needed for fractures of the metacarpals and phalanges. However, enough must be used to hold them in proper alignment. The pull must be applied with the finger held semiflexed in the position of function, never straight out as by a banjo splint. This cocks the bones out of alignment and stiffens the fingers.

Traction by adhesive plaster on skin is generally sufficient, but pulp traction is sometimes used. Care must be taken to avoid distraction with resulting non-union. Skeletal traction is rarely necessary except for Bennett's fracture, and here pinning with Kirschner wire is simple and effective. Rotatory malunion of the digits is avoided by checking to see that the plane of motion of the finger passes through the navicular tubercle and by observing the plane of the surface of the nail. Stiffening of adjoining fingers is avoided by splinting only the injured one on a curved outrigger from a cast over the hand and forearm and by keeping the other digits moving.

As stated above, casts must hold the wrist in dorsiflexion. They must respect the carpal arch, and terminate at the distal flexion and thenar creases in the palm, so that the proximal digital joints are free to flex. All uninjured parts must be kept moving. For metacarpal fractures, temporary pinning with Kirschner wires cut off beneath the skin to avoid infection is an excellent method. The hand does not become stiff because it is free from a cast.

The next type of crippling, namely *loss of motion from injury to tendons and nerves*, is best prevented by repairing the various structures early,—that is, within a few hours—and establishing good cover. Success is dependent on obtaining primary healing of the wound. In only selected clean-cut wounds can tendons be repaired within, but never after, twenty-four hours. Most such injuries should be repaired within one to

eight hours. Never should repair of tendons or deep structures be undertaken in badly contaminated, dirt-ground, or explosive wounds, or if serious infection is likely. The use of flexible, twisted, stainless-steel wire or removable wire for tendons, and the avoidance of dead spaces, hematomata, and buried sutures—especially of catgut—give the best conditions for healing. Only the simplest and minimum of suturing is used. For extensor tendons, a simple figure-of-eight suture is placed through the skin and tendon, in the hope that splinting will prevent pulling apart. There are many more principles and details that a surgeon must master before he will obtain good results in repairing tendons of the hand, and these can be gained only by study and application.

Injury to Nerves

Unless a surgeon is especially skilled in the suture of nerves, it is best merely to unite the two nerve ends with one stainless-steel wire. This prevents retraction of nerve ends, thus facilitating secondary suture. Primary nerve sutures as usually done frequently demand secondary accurate suturing under the best of surgical conditions. When, however, a primary nerve suture is done expertly, the regeneration is sooner and better than after a later repair.

Injuries to the nerves within the hand are important, for the hand is a sense organ, and for motions of skill the motor branches of the median and ulnar nerves are necessary. In débridement, care should be taken to spare all of these. The nerves are amply large for repair, and excellent recovery follows.

Injury of the nerves in the arm or brachial plexus cripples a hand as much as injury to the hand itself. The fate of the hand, which is the all-important part of the arm, is so dependent upon these nerves that their repair should take precedence over that of the bones and joints. Too often when this is not done, the paralyzed muscles and distal portions of the nerves undergo such irriversible fibrous atrophy that restoration of function is impossible. The sooner a nerve is repaired, the better, for the degeneration is progressive. After two years it is too late to restore motor function.

A hand paralyzed from arm injury needs to be kept mobile and in the position of function, or it becomes a useless shrunken claw in a position of non-function. Gentle physiotherapy is needed, as well as a light splint to substitute for the paralyzed muscles with just enough elastic force to balance the hand in the position of function. This exercises the hand and prevents the unopposed strong muscles from overstretching the paralyzed ones, thereby pulling the limb into deformity. The patient should be made to move his paralyzed hand and keep it in position by manipulating it with his other hand.

Painful neuromata may be avoided by preventing the scar tissue, which results from crushing wounds or infection, from forming around nerve ends. Thus amputation should be done in a clean field, and the nerve end placed in good tissue away from trauma.

Ischaemic contracture is preventable by guarding against circulatory interference. This should be watched for, especially in the anticubital space and after supracondylar fractures. Pressure or constriction here shuts off venous return, causing the limb to swell and be tight in a cast. Prompt decompression of the fascial compartment in the forearm and freeing of the vessels at the elbow will abort the process; early sympathectomy helps. The other type of ischaemic contracture,—that is, local in the hand, results from circulatory disturbance in the arm and from direct pressure on the clumped hand enclosed in a tight cast. The thenar and other intrinsic muscles become fibrosed and contracted. Even the use of excessive pressure in the treatment of burns may cause this.

Painful hands from aberrations of the vasomotor nervous system are best prevented by early recognition of the tendency in certain patients. These patients should not be treated over-sympathetically but encouraged to use their hands early and as long every day as possible in occupational therapy. They should be treated as workers instead of invalids so that such complications as Sudeck's atrophy or the tendency toward causalgia may be avoided.

Summary

For first aid the wound is covered by a sterile dressing and the patient taken to a well-equipped surgery where the definitive treatment is done under the best aseptic surgical conditions.

A careful examination and diagnosis of the injured structures is made. A plan of reconstruction is then decided upon. Consideration is given to the patient, his work, and his outlook. At this first treatment, digits may even be made to oppose each other for practical prehension and a plan of cover may be provided. One should consider what is left of the hand and the best way to preserve it and utilize it for prehension and sensation. Early treatment is merely the acute phase of plastic, orthopaedic, and peripheral-nerve surgery, all of which are needed for hand surgery.

The surrounding parts are shaved, washed with soap and water, and the wound is thoroughly irrigated with normal salt solution. Aseptic precautions are taken not to contaminate the wound with virulent germs from mouth and nose droplets or other contacts. The field is rendered bloodless by a pneumatic tourniquet, and the wound is debrided with as little trauma as possible. All usable parts are saved, particularly the nerves and tendons. Fractured bones are set, digits are placed in a position of function, and the skin cover is applied. Maximal length of the thumb is saved, and good workable cover is provided to the digital stumps. If a digit is discarded, its skin with vessels and nerves may be utilized for cover.

At first the damage is solely from the injury, but later there may be many complications, such as stiffened joints in the position of non-function and the others of the six main types of crippling already described in detail. These may be superimposed on the injury, but are directly due to the treatment.

Stiffening may be prevented by affording cover early, with the use of even a pedicle graft if necessary, by preventing infection, and by avoiding swelling and maintaining activity.

The available measures to prevent infection are early operation, early covering of all vulnerable parts with skin, the use of antibiotics, and refraining from attempting repair of deep structures where the wound is too old or too much traumatized.

Swelling can be avoided by elevation, fluff pressure dressings, and activity of the hand, exercising as much of it as possible and as early as possible, until the return to work.

Flexion contractures are avoided by preventing infection, establishing cover early, avoiding excess of granulations, and maintaining the position of function.

The latter is maintained by attention to the key joints, keeping the wrist in dorsiflexion, the proximal finger joints in flexion, the metacarpal arch curved, and the thumb in moderate opposition. Elastic splints may be used to change the deformed hand to one in the position of function.

Malalignment of bones is prevented by setting fractures and reducing dislocations early. Motion is preserved by repairing muscles and tendons early, whenever conditions permit, but never late in wounds or in traumatized tissue. Paralysis and loss of sensation are guarded against by recognizing early that nerves are injured and repairing them as soon as the conditions are right. The repair is usually done temporarily by merely securing the nerve ends together with one stitch of stainless-steel wire; secondary careful repair is done later. It is important that nerve repair be given priority over that of bones and joints, or fibrous degeneration of muscles and nerves will become irreversible.

Ischaemic contractures are avoided by not constricting the forearm and hand with dressings or casts, especially in the anticubital space and over the hand itself. A developing contracture may be aborted by prompt decompression and freeing the vessels.

Vasomotor disturbances are prevented by early recognition of the condition and by insisting on activity and the performance of work by the involved hands.

On reviewing these six main types of crippling and their mechanism of production, it is seen that much of the disability from injured hands can be prevented.

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Anales de Cirurgía. Numero de Aniversario de la IX Asamblea Nacional de Cirujanos (Mexico), 1951.
Anales de Ortopedia y Traumatologia (Montevideo), **3:** No. 3, 1951.
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News Notes

Applications for the 1952 Part II examinations of **The American Board of Orthopaedic Surgery** should be made before August 15, 1951, to the Secretary, Dr. Harold A. Sofield, 122 South Michigan Avenue, Chicago 3, Illinois.

Dr. O. L. Miller, after an absence from his office due to impaired health, has resumed practice with his associates of The Miller Orthopaedic Clinic, 123 West Seventh Street, Charlotte, North Carolina.

The Seventy-ninth Annual Meeting of the **American Public Health Association,** the Eighteenth Annual Meeting of its Western Branch, and the annual meetings of thirty-eight related organizations will be held simultaneously in San Francisco, October 29 to November 2, with headquarters at the Civic Auditorium. Further information may be obtained from Dr. Reginald M. Atwater, Executive Secretary of the Association, 1790 Broadway, New York 11, N. Y.

Announcement is made of the formation of the **Sociedad Portuguesa de Ortopedia,** with the following executive committee:

President: Dr. F. Pinto de Miranda
Vice-President: Dr. Abel da Cunha
Secretary: Dr. Antonio de Meneses
Treasurer: Dr. José Botelheiro

The address of the secretary is Rua Tenente Raul Cascais 11 A, Lisbon, Portugal.

The **Washington Orthopaedic Club,** of which Dr. William J. Tobin is President, plans to dedicate one of its meetings each year to the memory of a deceased member. The plan was inaugurated this year by the presentation of the Guy W. Leadbetter Memorial Lecture. Dr. Leadbetter was a founder of the Club and did much for the specialty.

The lecturer was Dr. Philip D. Wilson, Surgeon-in-Chief of the Hospital for Special Surgery, New York, who spoke on "Fractures of the Neck of the Femur and Their Complications".

The Fifth Congress of the **Pan-Pacific Surgical Association** will be held in Honolulu from November 10 to 21, 1951, under the presidency of Dr. F. J. Pinkerton.

The object of the Pan-Pacific Surgical Association is to bring together surgeons from countries bordering on the Pacific Ocean in order to permit the exchange of ideas and methods and to develop a spirit of good fellowship among the various races represented. Although it was originally planned to hold meetings every three years, world events have permitted but four conferences since the establishment of the organization,—the first in 1929 and the last in 1948.

Further information may be obtained by writing to the Pan-Pacific Surgical Association office, Suite 7, Young Building, Honolulu, Territory of Hawaii.

The **New Jersey Orthopaedic Society** offers an award of $100 for the best paper written on an orthopaedic or a closely related subject by a resident or intern in the State of New Jersey. The paper selected will be read by the author at the Spring Meeting of the New Jersey Orthopaedic Society in 1952.

Papers must be submitted to the Secretary of the New Jersey Orthopaedic Society, Dr. Philip Willner, 852 South 11th Street, Newark 8, New Jersey, on or before January 15, 1952.

The Second European **Congress of Rheumatology** of *La Ligue Europeenne contre le Rhumatisme,* planned by the host society *La Sociedad Española de Reumatismo,* will be held in Barcelona, Spain, September 24 to 27, 1951. All doctors interested in the treatment of rheumatism are invited to attend.

Requests for further information about the Congress should be sent to Dr. C. Alegre-Marcet, Via Layetana, 102, Barcelona, Spain. Registration should be made before August 15, 1951.

THE KAPPA DELTA AWARD FOR RESEARCH IN ORTHOPAEDIC SURGERY

A prize of $1,000, donated by the Kappa Delta Sorority, may be awarded annually by The American Academy of Orthopaedic Surgeons for the best research related to orthopaedic surgery done in the United States of America. This work must be presented to the Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons before November 1, 1951. Men doing research who are interested in competing for this prize are requested to secure further information from Dr. Austin T. Moore, Chairman of the Award Committee for 1951, Gervais and Pickens Streets, Columbia 5, South Carolina.

PLASTIC SURGERY AWARDS—1951

The Foundation of the **American Society of Plastic and Reconstructive Surgery** offers Junior and Senior Awards for original contributions in Plastic Surgery.

Junior Award: Two scholarships are given in plastic surgery for six and three months, respectively. The contest is open to plastic surgeons in the specialty not longer than five years.

Senior Award: For the best essay on "Mass Treatment of Burns in Atomic Warfare".

The winning essays will appear on the program of the forthcoming Annual Meeting of the American Society of Plastic and Reconstructive Surgery to be held at Colorado Springs, Colorado, from October 31 to November 2, 1951.

All entries must be received by the Chairman not later than August 15, 1951. For full particulars write to: The Award Committee, c/o Jacques W. Maliniac, M.D., 11 East 68th Street, New York 21, N. Y.

The Ohio Orthopaedic Society held its Annual Meeting in Toledo, Ohio, on April 13 and 14, 1951, under the presidency of Dr. Albert L. Bershon, at St. Vincent's Hospital.

The program included the following papers:

Management of Bony Metastasis: Dr. C. E. Hufford, Dr. F. C. Curtzwiler, Dr. Ulrich, and Dr. S. Asahina.
Elephantiasis of Lower Extremity: Dr. J. Gosman.
Chordoma of Cervical Spine: Dr. M. Schnitker, Dr. Booth, and Dr. Hopple.
Diaphyseal Aclasia with Paraplegia: Dr. M. Schnitker, Dr. Booth, and Dr. Hopple.
Tendon Transplants in Lead Palsy: Dr. J. Kelleher.
Unusual Knee Arthrotomy Findings: Dr. J. W. Millis.
Tumor of Shoulder Joint. Surgical Excision: Dr. T. H. Brown and Dr. N. T. Barnes.
Chondroma of Astragalus: Dr. T. H. Brown and Dr. N. T. Barnes.
Discussion of the Ohio Indemnity Plan: Dr. C. Mundy.
A Case of Hip Trauma: Dr. J. Pollex.
The Problem of Trimalleolar Fractures: Dr. J. Pollex.
Demonstration of Fracture Cases: Dr. Sheib and Dr. Skopek.
Bone Tumors: Dr. Sheib and Dr. Skopek.
Problems in Surgery of the Hip: Dr. A. L. Bershon.
Severe Shoulder Injury: Dr. N. Hein.
Arthroplasty of the Hip: Dr. Hawkins and Dr. Young.
Early Epiphyseal Closure at the Elbow: Dr. Hawkins and Dr. Young.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-fourth Annual Meeting of The American Orthopaedic Association was held at The Greenbrier, White Sulphur Springs, West Virginia, on June 20, 21, 22, and 23, 1951, under the presidency of Dr. James S. Speed.

The Program Committee, Dr. John Royal Moore, Chairman, provided the following interesting scientific program

WEDNESDAY, JUNE 20

Afternoon Session

The Inorganic Component of Bone as Demonstrated by the Electron Microscope.
Robert A. Robinson, M.D., Rochester, New York (by invitation).
Discussion: Robert W. Johnson, M.D., Baltimore, Maryland;
Joseph S. Barr, M.D., Boston, Massachusetts.

A Comparative Study of Bone-Grafting Materials.
Robert D. Ray, M.D., Seattle, Washington (by invitation).
Discussion: Edwin F. Cave, M.D., Boston, Massachusetts;
J. Albert Key, M.D., St. Louis, Missouri.

Treatment of Non-Union in Compound Fractures with Infection.
Mather Cleveland, M.D., New York, N. Y.;
Edward M. Winant, M.D., New York, N. Y. (by invitation).
Discussion: LeRoy C. Abbott, M.D. (read by Frederic C. Bost, M.D.), San Francisco, California;
Frank Stinchfield, M.D., New York, N. Y.;
John L. McDonald, M.D., Toronto, Ontario, Canada;
Charles W. Peabody, M.D., Detroit, Michigan;
Leo Mayer, M.D., New York, N. Y.

Pedicle Bone Graft in Congenital Pseudarthrosis.
A. W. Farmer, M.D., Toronto, Ontario, Canada.
Discussion: Arthur B. LeMesurier, M.D., Toronto, Ontario, Canada;
John R. Moore, M.D., Philadelphia, Pennsylvania;
I. William Nachlas, M.D., Baltimore, Maryland.

End-Result Study of the Surgical Treatment of Perthes Disease.
Paul B. Steele, M.D., Pittsburgh, Pennsylvania.
Discussion: A Bruce Gill, M.D., Philadelphia, Pennsylvania;
William T. Green, M.D., Boston, Massachusetts;
R. M. Wansbrough, M.D., Toronto, Ontario, Canada;
John A. Heberling, M.D., Pittsburgh, Pennsylvania.

THURSDAY, JUNE 21

Morning Session

Effect of Cortisone on the Healing of Experimental Fractures.
J. Albert Key, M.D., St. Louis, Missouri;
R. Odell, M.D., St. Louis, Missouri (by invitation);
Lloyd Taylor, M.D., St. Louis, Missouri (by invitation).
Discussion: Carl E. Badgley, M.D., Ann Arbor, Michigan;
Keene O. Haldeman, M.D., San Francisco, California;
Philip D. Wilson, M.D., New York, N. Y.;
Edgar M. Bick, M.D., New York, N. Y.

Experimental Studies in Transplantation of Whole Joints.
Charles H. Herndon, M.D., Cleveland, Ohio (by invitation).
Discussion: Philip D. Wilson, M.D., New York, N. Y.;
Clarence H. Heyman, M.D., Cleveland, Ohio;
Francis M. McKeever, M.D., Los Angeles, California;
J. Albert Key, M.D., St. Louis, Missouri.

Stenosing Tenosynovitis—A Simplified Surgical Management.
Walter C. Graham, M.D., Santa Barbara, California.
Discussion: Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania;
Leo Mayer, M.D., New York, N. Y.;
Joseph A. Freiberg, M.D., Cincinnati, Ohio;
J. Vernon Luck, M.D., Los Angeles, California;
Sterling Bunnell, M.D., San Francisco, California.

Recurrent Dislocation of the Patella.
Ian Macnab, M.D., Toronto, Ontario, Canada (by invitation).
Discussion: Fremont A. Chandler, M.D., Chicago, Illinois;
John L. McDonald, M.D., Toronto, Ontario, Canada;
Charles W. Peabody, M.D., Detroit, Michigan;
J. Albert Key, M.D., St. Louis, Missouri;
E. B. Mumford, M.D., Indianapolis, Indiana.

Sarcomata of the Soft Somatic Tissues.
George T. Pack, M.D., New York, N. Y. (by invitation).

Periarticular Calcification following Poliomyelitis.
Joseph A. Freiberg, M.D., Cincinnati, Ohio.
Discussion: Wallace H. Cole, M.D., Minneapolis, Minnesota;
J. Warren White, M.D., Honolulu, Hawaii;
Edward L. Compere, M.D., Chicago, Illinois.

Replacement Reconstruction of the Hip.
Harold R. Bohlman, M.D., Baltimore, Maryland (by invitation).
Discussion: Leonard T. Peterson, M.D., Washington, D. C.;
Walter P. Blount, M.D., Milwaukee, Wisconsin;
Dallas B. Phemister, M.D., Chicago, Illinois.

FRIDAY, JUNE 22

Morning Session

Treatment of Congenital Dislocation of the Hip by Colonna Type of Arthroplasty.
Frederic C. Bost, M.D., San Francisco, California;
Edwin R. Schoffstedt, M.D., San Francisco, California (by invitation);
Loren J. Larsen, M.D., San Francisco, California (by invitation).
Discussion: Paul C. Colonna, M.D., Philadelphia, Pennsylvania;
H. Relton McCarroll, M.D., St. Louis, Missouri;
Walter P. Blount, M.D., Milwaukee, Wisconsin;
Willis K. West, M.D., Oklahoma City, Oklahoma.

Some Histophysiological Problems Peculiar to Calcified Tissues.
Arthur W. Ham, M.D., Toronto, Ontario, Canada (by invitation).

The Present Status of Surgery in Rheumatoid Arthritis with Special Reference to Experience with Cortisone.
William H. Bickel, M.D., Rochester, Minnesota;
Ralph K. Ghormley, M.D., Rochester, Minnesota.
Discussion: G. E. Haggart, M.D., Boston, Massachusetts;
J. Vernon Luck, M.D., Los Angeles, California;
Robert W. Johnson, M.D., Baltimore, Maryland.

Presidential Address.
James S. Speed, M.D., Memphis, Tennessee.

SATURDAY, JUNE 23

Morning Session

The Normal Osteohistology of the Senescent Vertebra.
Edgar M. Bick, M.D., New York, N. Y.;
Joseph Copel, M.D., Boston, Massachusetts (by invitation).
Discussion: Arthur Steindler, M.D., Iowa City, Iowa.

Iliopsoas Transfer for Hip Abductor Weakness.
W. T. Mustard, M.D., Toronto, Ontario, Canada (by invitation).
Discussion: Edward L. Compere, M.D., Chicago, Illinois;
Charles W. Peabody, M.D., Detroit, Michigan;
Leo Mayer, M.D., New York, N. Y.;
J. Albert Key, M.D., St. Louis, Missouri;
Beckett Howorth, M.D., New York, N. Y.;
George J. Garceau, M.D., Indianapolis, Indiana.

Symposium: Streptomycin in Bone and Joint Tuberculosis.
David M. Bosworth, M.D., New York, N. Y.;
F. P. Dewar, M.D., Toronto, Ontario, Canada (by invitation).
H. F. Coulthard, M.D., Toronto, Ontario, Canada (by invitation);
E. T. Evans, M.D., Minneapolis, Minnesota (by invitation);
Philip Moore, M.D., Mt. Edgecumbe, Alaska (by invitation).
Discussion: Ralph K. Ghormley, M.D., Rochester, Minnesota;
Alan DeForest Smith, M.D., New York, N. Y.;
J. Albert Key, M.D., St. Louis, Missouri.

Arthroplasty of the Elbow.
Robert A. Knight, M.D., Memphis, Tennessee (by invitation);
I. L. Van Zandt, M.D., Memphis, Tennessee (by invitation).
Discussion: George E. Bennett, M.D., Baltimore, Maryland;
Leo S. Lucas, M.D., Portland, Oregon.
Charles R. Rountree, M.D., Oklahoma City, Oklahoma;
Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania;
Philip D. Wilson, M.D., New York, N. Y.

Report of Joint Committee on Military Affairs.
Edward T. Evans, M.D., Minneapolis, Minnesota.

There were Executive Sessions on Wednesday at 1:00 P.M. and on Saturday at noon. The Annual Banquet was held Friday evening.

Dr. Fremont A. Chandler, of Chicago, is President for the year 1951–1952.

At the Executive Session on Saturday the following officers, members of committees, and delegates were elected:

Officers

President-Elect: James A. Dickson, M.D., Cleveland, Ohio.
Vice-President: Harold H. Hitchcock, M.D., Oakland, California.

Secretary: C. Leslie Mitchell, M.D., Detroit, Michigan.
Assistant Secretary: George O. Eaton, M.D., Baltimore, Maryland.
Treasurer: H. Page Mauck, M.D., Richmond, Virginia.

Committee Members

Membership Committee: Edwin F. Cave, M.D., Boston, Massachusetts.
Program Committee: T. Campbell Thompson, M.D., New York, N. Y.
Research Committee: I. William Nachlas, M.D., Baltimore, Maryland.

Delegate to the American College of Surgeons

Philip D. Wilson, M.D., New York, N. Y.

Representatives on The American Board of Orthopaedic Surgery

Paul C. Colonna, M.D., Philadelphia, Pennsylvania.
George J. Garceau, M.D., Indianapolis, Indiana.

The following members were elected:

Honorary Members

Sterling Bunnell, M.D., San Francisco, California.
John B. deC. M. Saunders, M.B., San Francisco, California.

Corresponding Members

Sten Friberg, M.D., Stockholm, Sweden.
H. Osmond-Clarke, F.R.C.S., London, England.

Active Members

Otto E. Aufranc, M.D., Boston, Massachusetts;
George W. N. Eggers, M.D., Galveston, Texas;
C. Fred Ferciot, M.D., Lincoln, Nebraska;
Julian E. Jacobs, M.D., Charlotte, North Carolina;
Emanuel B. Kaplan, M.D., New York, N. Y.;
Claude N. Lambert, M.D., Chicago, Illinois;
Carroll B. Larson, M.D., Iowa City, Iowa;
Don H. O'Donoghue, M.D., Oklahoma City, Oklahoma;
Charles N. Pease, M.D., Chicago, Illinois;
Fred C. Reynolds, M.D., St. Louis, Missouri;
Francis E. West, M.D., San Diego, California;
Edward M. Winant, M.D., New York, N. Y.

The meeting next year will be a joint meeting with The British Orthopaedic Association and will be held in London, June 30, July 1 to 4, 1952.

The Fifty-eighth Annual Convention of the **Association of Military Surgeons of the United States** will be held at the Palmer House in Chicago, October 8 to 10. Members of allied medical services such as nursing, dentistry, veterinary medicine, women's medical specialty corps, and medical service corps, as well as physicians, will participate in the sessions. Advances in military medicine since World War II, and current problems arising out of the critical world situation and the Korean conflict, will be discussed. Col. James M. Phalen, U.S.A. (Ret.), is Secretary of the Association and also Editor of its official journal, the "Military Surgeon".

A gift of $10,000 has been made to the National Society for Crippled Children and Adults by **Alpha Chi Omega.** This gift brings to a total of $35,000 the grants made by this Sorority to the National Society, for advanced study in the care and treatment of cerebral-palsied children.

The International Congress of Physical Medicine, organized by the British Board of Management of the International Federation of Physical Medicine, will be held in London from July 14 through July 19, 1952, under the presidency of Lord Horder.

The meetings of the Congress will be reserved for matters dealing with the clinical, remedial, prophylactic, and educational aspects of physical medicine and the diagnostic and therapeutic methods employed in physical medicine and rehabilitation.

In addition are planned technical, scientific, and historical exhibitions, as well as a full program of social events for members and associate members. Arrangements for visits of scientific and historical interest both in London and in the country are being made for the week of the Congress and the week following the Congress.

Applications for the provisional program should be addressed to the Honorary Secretary, A. C. Boyle, M.D., International Congress of Physical Medicine (1952), 45 Lincoln's Inn Fields, London, W.C. 2.

NICHOLAS S. RANSOHOFF

1896–1951

After a gallant struggle lasting for more than two years, Dr. Nicholas Ransohoff died on April 25, 1951, at his home in Long Branch, New Jersey. His death is mourned not only by his immediate family and close friends, but by hundreds of patients, many of them victims of poliomyelitis, who regarded Dr. Ransohoff with a love and veneration seldom accorded to any human being.

Born in Salt Lake City, Utah, fifty-five years ago, Dr. Ransohoff received his medical degree from the Columbia University College of Physicians and Surgeons in 1919. He served as an intern at the Lenox Hill Hospital in New York; and, following his graduation, he became attached to the general surgical staff of that Hospital.

It was not until 1925 that he became interested in orthopaedic surgery. At that time, severe pain developed in his feet, and for months he was unable to obtain any relief. When eventually, through an accurate orthopaedic examination, the cause of his disability was discovered and his pain was promptly relieved, his eager mind was stimulated to study orthopaedic problems. He began intensive work at the Hospital for Joint Diseases and in private practice with Dr. Leo Mayer.

After a year, he continued his studies abroad, in Italy under Putti, in Germany under Biesalski, Lange, and Hohmann, and in England under Sir Robert Jones. There he became friendly with Reginald Watson-Jones, Harry Platt, Osmond-Clarke, and other rising British surgeons. On his return he was made an Associate Attending Surgeon at the Hospital for Joint Diseases, a position which he held for about fifteen years. During this period he did much to help develop the concept of paralytic pelvic obliquity, and his thesis for admission to The American Orthopaedic Association was devoted to a critical evaluation of the first twenty-five cases in which fascial abdominal grafts were used for the correction of this condition.

He was also fascinated by the problems of tendon surgery of the hand; and, with Mayer in 1936, he evolved the method of implantation of celloidin tubes to reconstruct the gliding pathway within fingers where the digital sheaths had been completely destroyed. Because of his general surgical training, he was able to develop an outstanding technique for orthopaedic operations.

In addition to his activity at the Hospital for Joint Diseases, he inaugurated an orthopaedic and traumatic service at the Monmouth Memorial Hospital in Long Branch, New Jersey. This service developed so rapidly that in 1942 he resigned from the Hospital for Joint Diseases in order that he might concentrate on his activity at the Monmouth Memorial Hospital. It was there, during an extensive local epidemic of poliomyelitis, that he first began to treat the muscle spasm of this disease with injections of curare. A patient showing unusually severe painful spasm could not be relieved by the application of hot packs. The thought occurred to Dr. Ransohoff, who at the Hospital for Joint Diseases had had frequent occasion to observe the beneficial relaxing effect of curare in cases of cerebral palsy, that the drug might be equally effective in relieving the spasm of poliomyelitis. The first injection had an amazing effect: the child who had been screaming with pain was within ten minutes completely relieved. This dramatic result led Dr. Ransohoff to a systematic use of the drug in all the early cases of poliomyelitis admitted to his Service. He never claimed any therapeutic properties for curare, but he felt very strongly that it was a much more potent form of giving relaxation than the Kenny method. To study the physiology of paralyzed, spastic, and normal muscles, he developed a machine for measuring and recording their electrical reactions. This machine was housed in a special room, carefully insulated, into which no one was admitted except by Dr. Ransohoff's permission. This was his "Holy of Holies"; here he spent every available spare hour. Thousands of electromyographic records were made, which he studied night after night. He had the conviction that electromyography would develop an importance for the orthopaedic surgeon equivalent to that of the electrocardiogram for the heart specialist. Death interrupted this work before its goal could be reached.

Dr. Ransohoff was President of the New Jersey Orthopaedic Society, a fellow of The American Academy of Orthopaedic Surgeons, and a member of The American Orthopaedic Association. In addition to being Director of Orthopaedic Surgery at the Monmouth Memorial Hospital, he was Consulting Orthopaedic Surgeon to the Children's Country Home, Long Branch; the Betty Bacharach Home for Crippled Children, Atlantic City; Fitkin Memorial Hospital, Neptune; Riverview Hospital, Red Bank; and the Paul Kimball Hospital in Lakewood.

To his friends, Dr. Ransohoff was always "Nick". They loved him for his charm, his enthusiasm, his outgoing warmth, his eager desire to learn and to contribute to orthopaedic advance, his rectitude, and his kindness to little children and to the crippled adult. By his death they have lost a comrade whose place can never be filled.

Book Reviews

THE PHYSIOLOGY AND PATHOLOGY OF EXPOSURE TO STRESS. A Treatise Based on the Concepts of the General-Adaptation-Syndrome and the Diseases of Adaptation. Hans Selye, M.D., Ph.D. (Prague), D.Sc. (McGill), F.R.C.S. (Canada). Montreal, Acta, Inc., 1950. $14.00.

Every now and then a new concept of a biological process is introduced which sheds new light on the understanding of that process. For the bacteriologist, Ehrlich's side-chain theory concerning the origin of antibodies dominated reasoning in this field for many years. For the physiologist, the researches of Walter B. Cannon led to the evolution of the "emergency theory" of the adrenal medulla. This theory led to controversy and supplied many a research problem in the course of proving or disproving it. It shed new light on the understanding of such seemingly unrelated phenomena as elevation of blood pressure, hyperglycaemia, and the motility of the gastro-intestinal tract. Now for the general broad field of clinical medicine (included is the field of surgery, as well as all the specialties), we have a concept of disease recently set forth which may prove to be of the same magnitude of importance as other concepts which have preceded it in the biological sciences. The concept is that of the general adaptation syndrome, described in general and in great particular by its originator, Hans Selye.

The general adaptation syndrome represents the evolution of certain ideas first set forth by Selye in 1936. As a keen observer of the reaction of experimental animals to induced stress affecting large portions of the body (such as cold, fatigue, intoxications), he noted a repeated pattern of response. There was first the phase of *shock* or a condition characterized by sudden severe, general damage lasting from a few minutes to about twenty-four hours and a *counter-shock* phase in which the organism mobilized its defenses against the damaging agents. The dual entities were referred to as the "alarm reaction", *alarm* being used in the sense of *stimulus* or the rallying call of defense forces of the organism. The reaction pattern was of interest, in that response showed the same characteristics, although the variety of systemic stresses was great.

This original concept then was enlarged to include two subsequent stages, provided that the stress continued. There was the stage of *resistance* which often was remarkable in its duration, although even the perfectly adapted organism could not maintain itself indefinitely in this stage. When adaptation could no longer be maintained, the stage of *exhaustion* was reached. Finally, there was conceived what is now termed the "general-adaptation-syndrome" which was considered to embrace the alarm reaction (with its two phases), the phase of resistance, and the phase of exhaustion.* It will be in the interests of further elucidation to quote directly from Dr. Selye's book:

"The reaction is *general;* it is elicited only by those stresses which are generalized (in that they affect large portions of the body) and it in turn evokes generalized, systemic defense phenomena.

"The reaction is *adaptive;* it helps the acquisition and maintenance of a state of inurement.

"The reaction is a *syndrome;* its individual manifestations are coordinated and partly even interdependent."

One further extension of the concept is in order at this point, because it is here that this new light focuses most brightly on the interests of the clinician. It has been conceived that many of the maladies of man which are dealt with daily in all parts of our hospitals are *diseases of adaptation;* that is, representations of the "derailment" of the adaptation process. The adaptive reaction may be subdivided into insufficient, excessive, or abnormal reactions, and it becomes possible to fit almost any disease process into one of the phases or subphases described in the total concept just summarized.

To the general practitioner and the specialist new illumination has been given in which he may view and explore the manifestations of disease; the hypertensive patient, the patient with ulcer, the suspected diabetic now becomes the subject in which a search for stress is sought. For the orthopaedist, the findings of osteoporosis may impel him to seek an explanation in the depleted body proteins as a manifestation of the

* Those interested in physiological or pathological manifestations of the various phases may find them summarized as follows: (1) Shock phase was characterized by hypothermia, hypotension, depression of the nervous system, decrease in muscle tone, hemoconcentration, deranged capillary and cell-membrane permeability, generalized tissue breakdown ("catabolic impulse"), hypochloraemia, hyperkalaemia, acidosis, a transitory rise followed by a decrease in blood-sugar, leucopenia followed by leucocytosis, eosinopenia and acute gastro-intestinal erosions. (2) Counter-shock manifested itself by a reversal of most of the changes observed in Stage 1, that is, hypertension, hyperglycaemia, *et cetera.* These changes were synchronous with the stimulation of adrenal cortical activity and were held to be dependent upon the discharge of adrenal cortical substances into the blood. (3) The stage of resistance was entered into imperceptibly if the stress was chronic, and here the manifestation of Stage 2 continued and reached the maximum degree of development. (4) The stage of exhaustion was characterized by the reappearance of many lesions noted in 1 and 2, — such as involution of thymico-lymphatic system, loss of adrenal lipids, gastro-intestinal ulcers. This final stage represented the loss of maintenance of adaptation.

stage of counter-shock.* He can hardly help but be fascinated by the section in which joint disease is integrated into the adaptation syndrome.

This concept, or theory, like all preceding theories, is subject to controversies, misunderstandings, and misapplications; time, together with observation and experimentation, will give the final answer as to its validity. It is to be hoped that, with the understanding of the manifestations of stress, some relief from the symptoms may be supplied. If the theory serves nothing more than to integrate a large number of isolated observations into one logical and comprehensible whole, its value will have been in no measure small.

The book itself serves as a reference source for those who wish to pursue in detail descriptions of the various phases of the general adaptation syndrome as they apply to systems (skeletal, hemopoietic, lymphatic, cardiovascular, respiratory, muscular, nervous, gastro-intestinal) and organs (liver, kidney, *et cetera*). The bibliography is extensive and should be of great value to those wishing to consult original papers.

A Text-Book of X-Ray Diagnosis. By British Authors. Ed. 2, Vol. IV. Edited by S. Cochrane Shanks, M.D., F.R.C.P., F.F.R., and Peter Kerley, M.D., F.R.C.P., F.F.R., D.M.R.E. London, H. K. Lewis and Co., 60 Shillings; Philadelphia, W. B. Saunders Company, 1950. $15.00.

The Second Edition of the *Textbook of X-ray Diagnosis*, edited by Shanks and Kerley, has recently been published. This textbook, formerly published as one volume, is now divided into four separate volumes. Volume IV, the one under review, deals with the bones, joints, and soft tissue. The material has been written by several contributors, and the book is divided into eleven parts with many subgroups and chapters. The conciseness of many of the chapters will have a definite appeal. The book as a whole, however, lacks coordination and compactness in some parts; and, in others, it is sketchy, incomplete, and overlapping.

Of especial interest are *Part I* and *Part II*. *Part I* presents briefly, but clearly, the roentgenographic anatomy of the various bones and joints, a subject not sufficiently stressed in many textbooks. This is accompanied by a description of the common anomalies which often are confusing to the roentgenologist and specialist alike. The description of the many sesamoid bones has particular interest. An excellent chapter describes the procedure of examination, detailing the standard views required to make it satisfactory.

Somewhat greater emphasis could have been placed upon the variations of growth and the structural appearance of bones and joints in childhood. Certain developmental features, such as centers of ossification and time of first appearance among others, are mentioned, but it seems to the reviewer that the subject should have been discussed in greater detail.

Part II deals with the physiology and pathology of the bone structure. The various types of bone structures, the physiology of periosteum and endosteum; the physiology and pathology of the formation and deposition of bone, calcification of the bone matrix, normal growth, and reconstruction under pathological conditions are all covered. Bone erosion and destruction, necrosis, and new bone formation are discussed; and the differential points in roentgenographic diagnosis are brought out. The changes in the calcium content of bone and its reflection upon the roentgenographic density are mentioned, as well as the effects of infection, tumors, and metabolic disturbances upon the general physiology of bone.

Nine parts are devoted to specific problems, among which are congenital deformities, traumatic lesions, inflammatory and constitutional disease, static and paralytic lesions, tumors, cysts, and lesions of soft tissue among others. Some of these chapters are excellent; others are somewhat too brief and sketchy. One of the latter deals with orthopaedic operations and their reflection upon the roentgenographic appearance of bone. The chapters on osteochondritis and on paralytic and neurotrophic disturbances could have been enlarged. Congenital malformations, fractures and dislocations, and particularly inflammatory disease of the bones and joints, including the various types of arthritis, are well presented. The final Part briefly describes various methods of localization of foreign bodies.

On the whole, the authors are to be congratulated on making available a textbook which, despite a few shortcomings, is among the best written in the English language. Excellent illustrations of roentgenograms accompany the text. A good index and bibliography, which too often are neglected, add value to this textbook. It is to be recommended to all those interested in the roentgenographic aspects of bone conditions.

The Pathology of Articular and Spinal Diseases. Douglas H. Collins, O.B.E., M.D. (Liverpool). London, Edward Arnold & Co. 35 Shillings; Baltimore, The Williams and Wilkins Company, 1950. $7.00.

Most pathologists in this country have neglected the study of joints, especially of the spine, probably because of autopsy restrictions,—at least that is one of the excuses often given. It is therefore very gratifying to welcome Dr. Collins's little volume on his personal experience with the morbid anatomy of joint disease during the past fifteen years in hospitals in Leeds, Sheffield, and Liverpool.

The book contains seventeen chapters, including two on the anatomy, embryology, and physiology of joint tissues. About a third of the book is devoted to osteo-arthritis, rheumatoid arthritis, and rheumatic

* See also p. 182 *In* The Parathyroid Glands and Metabolic Bone Disease, by Fuller Albright and E. C. Reifenstein, Jr. Baltimore, Williams and Wilkins Co., 1948.

fever; a third to the diseases of the spine; and the remainder to such conditions as trauma, gout, infections, and tumors. The author also includes a very short chapter on the pathology of many of the common disorders of bone, "written mainly from the standpoint of the clinician, who has the x-ray of the patient in his hand". Since so many conditions are covered in this short chapter, each is by necessity so scanty that this reviewer believes it would have been better to have omitted it. Perhaps this space could have been better used for more reproductions of roentgenograms, even though the author states in his preface that he is omitting them purposely, since there are so many roentgenographic atlases devoted to this subject. This reviewer also feels that the value of the gross specimen is increased by having its corresponding x-ray shown. It would have been preferable, therefore, to sacrifice some of the photographs of patients with osteo-arthritis and rheumatoid arthritis in order to include more reproductions of roentgenograms.

The photographs of the gross and microscopic specimens are excellent. They are all taken from the author's own cases. The clarity of detail in these black and white figures, which number nearly 200, leaves nothing to be desired.

The author prefers the use of the term "osteo-arthritis" rather than "degenerative joint disease", the term more often used in this country. "It is more accurate in my opinion to say that the initial lesion of osteo-arthritis is destruction rather than degeneration of articular cartilage, since destruction of previously healthy cartilage will precipitate the condition, whereas degeneration alone without the destructive trauma will not do so. A disused joint never developed osteo-arthritis. A misused one often does." This chapter and the two on rheumatoid arthritis are beautifully and clearly presented and illustrated. Although most authors agree that little has been added to the anatomical differentiation and description of these two conditions since that of Nichols and Richardson in 1909, Dr. Collins's presentation is one of the best that has appeared in recent years; it is highly recommended to physicians interested in joint disease.

LEHRBUCH DER RÖNTGENDIAGNOSTIK (Textbook of Diagnostic Radiology). 5. Auflage, 3. Lieferung. Skelett. H. R. Schinz, W. E. Baensch, E. Friedl, und E. Uehlinger. Stuttgart, Georg Thieme, 1951. (Distributed by Grune and Stratton, Inc., New York, N. Y.)

In reviewing the third volume of such an unusual book as the *Textbook of Diagnostic Radiology* by Schinz and his collaborators, it is difficult to avoid being repetitious in the expression of praise.

Volume III is a direct continuation of *Volume II*, and deals further with conditions of the bones and joints. Like the two preceding volumes, it is characterized by an excellence of text, diagrams, tables, bibliography, and roentgenographic reproductions.

The book is divided into four major parts. Malignancy of bone, malformation of bone, systemic diseases of bone, and the various types of arthropathies are the problems dealt with in the respective sections.

The many types of primary bone tumors are excellently presented, particular emphasis being placed on the discriminating features and differential diagnostic points of each condition. Even the expert diagnostician will find information of inestimable value in these pages.

One wonders at the extent of the knowledge displayed in the chapter on metastatic bone lesions, a chapter of particular interest and importance. An attempt has been made to coordinate the modes of metastasis and to correlate the predominant occurrence of secondary tumors in relation to the primary site of a given type of tumor. Certain statistical conclusions in regard to the location of the primary tumor, based on the location and characteristics of the metastatic manifestations, have been drawn. Analysis of the frequency of pathological fractures in bone tumors, metastatic from different primary sites, furnishes an important contribution on this subject. An unexpected and unfortunate omission, however, is the lack of discussion of the influence of hormonal therapy on metastatic bone lesions.

The second part of the book deals with malformations of the skeleton, including some of the more bizarre varieties. This chapter should be of value particularly to the pediatric and orthopaedic surgeons, who by necessity must be well informed on these conditions which appear rather dry and uninteresting to the average roentgenologist. The reader will be stimulated by a superb text, numerous illustrations, charts, and tables of development and heredity.

In the third section, the many diseases of bone related to various metabolic and constitutional disturbances are discussed. In it are included vitamin deficiencies, hormonal imbalances, and allied disorders. As in the other sections of the book, the accompanying tables of distribution, roentgenograms, and photographs make the many complex and confusing features of these diseases more comprehensible to the reader than an unillustrated text.

If any distinction can be made, the chapters dealing with diseases of the joints may be recommended as the best. This section is almost a monograph in itself. Of special interest is the discussion on the various types of arthrography. There are excellent descriptions of different techniques and methods, the relative merits of which are compared. Normal and pathological findings of arthrographic studies of the temporomandibular, shoulder, and knee joints are given; and various types of derangement of the knee joint are demonstrated.

Traumatic changes of the joints—dislocations, subluxations, and contusions—are well presented, as are the various arthritides. Many points in the differential diagnosis of infectious arthritis, rheumatoid arthritis

with its numerous manifestations, as well as degenerative changes including those resulting from neurotrophic disturbances, are brought out.

An interesting chapter treats of hereditary diseases of the joints, including those in hemophilia, alkaptonuria, congenital dislocations, and others. Neoplastic joint diseases, however, are covered rather briefly; Baker's cysts are not mentioned, and the discussion of synovioma is too sketchy for a malignant lesion of its importance,—a tumor which is not uncommon and which in recent years has been the subject of extensive study in this country.

A short description of ankyloses, arthroplasties, osteotomies, and regeneration of joints concludes *Volume III*.

Like the two preceding volumes, this book is outstanding in its comprehensive presentation of all the problems under discussion. Roentgenographic, clinical, and pathological studies are combined to make this of greater value and interest than the usual type of textbook. This effort to coordinate pertinent roentgenographic problems in the light of modern clinical and pathological knowledge in itself represents an accomplishment which demands the respect and gratitude of all those who have an opportunity to study this work. Schinz and his collaborators are to be congratulated on making this admirable textbook available to the medical profession.

THE CLOSED TREATMENT OF COMMON FRACTURES. John Charnley, B.Sc., M.B., F.R.C.S. Edinburgh, McLagan and Cumming, Ltd.; Baltimore, The Williams and Wilkins Company, 1950. $7.00.

Mr. Charnley has summed up in a very concise and expertly illustrated text the closed treatment of the more common fractures. His approach is new and stimulating: In his preface, he outlines his primary thesis, ". . . . an attempt is here made to re-emphasize the non-operative method, and to show that far from being a crude and uncertain art, the manipulative treatment of fractures can be resolved into something of a science".

Throughout his book, Mr. Charnley first creates a mental picture of the fracture deformity with its damaged and undamaged soft parts. It is with this concept of damaged soft parts and intact supporting soft tissues that the mechanics of reduction and maintenance of reduction are made clear. Wooden models with a strip of leather, representing the intact periosteum and fibrous structures, illustrate typical fractures.

The chapter on "Plaster Technique" demonstrates effective and safe methods of successful plaster applications.

The author has included in this book his original observations on the cause and prevention of joint stiffness, and he reviews the factors which govern the recovery of joint movement following a fracture. This subject is well considered from mechanical, biological, and physiological aspects. Mr. Charnley will stimulate the reader to further thought on this subject.

The section on the design and use of the Thomas caliper splint contains an interesting historical review of this very important piece of apparatus with many practical suggestions for its correct use.

Although the book is addressed primarily to the young casualty surgeon, a busy fracture surgeon will find sound reasoning and a timely emphasis on indications and methods of closed treatment of fractures. Sir Harry Platt aptly states in the Foreword of the book: "There is much in this monograph which will persuade the experienced orthopaedic surgeon to re-examine some of his most cherished pre-suppositions".

PLASTIC AND RECONSTRUCTIVE SURGERY. A Manual of Management. Ferris Smith, M.D., F.A.C.S. Philadelphia, W. B. Saunders Company, 1950. $15.00.

The author of "Plastic and Reconstructive Surgery", Dr. Ferris Smith, has been one of the leaders in American plastic surgery during the past thirty years. Sections of the *Military Manual of Plastic and Maxillofacial Surgery*, published during World War II, were edited by him and form the basis for the present volume.

The first four chapters of this book deal with general consideration of patient care, tissue transplantation, the multiple problems of facial clefts, fractures of the face, burns, wound healing, dental prosthesis, and the principles of planning and execution of operative procedures. The remaining chapters are concerned with regional problems, chiefly those of the face, head, and neck, but chapters dealing with the trunk and the extremities are also included. In each of the latter chapters, the author presents illustrative cases and discusses selection of the method of correction. The surgical procedures in each case are related in detail with a step-by-step description of the technique.

The author emphasizes throughout the text what he calls the "cosmetic disability" and discusses the tendency to use skin grafts and remote flaps for repairs which could be accomplished by the proper utilization of local tissue. This principle deserves consideration and has an influential champion in Dr. Smith. It has functional limitations, however, because the mobility of any part of the body depends on an adequate "skin envelope" in which to move. For example, the use of multiple local flaps in the hand crippled by a burn contracture can never provide as satisfactory a functional result as can a skin graft.

This volume will prove stimulating to those contemplating a career in plastic surgery. It should also be a valuable reference book to any who are confronted by surgical problems in plastic and reconstruction surgery and need helpful detailed guidance of how to proceed. A vast store of clinical experience is represented in this book.

FRACTURAS DEL EXTREMO INFERIOR DEL RADIO (Fractures of the Lower End of the Radius). José A. H. Bulfaro. Buenos Aires, Editorial Universitaria, 1947.

This is an excellent example of the increasing number of practical orthopaedic monographs which are being written by our South American confrères. The author discusses the normal anatomy of the lower end of the radius and its relation to the pathological deviations.

He then reviews the history of fractures in the lower end of the radius. Only fractures of the fingers are more common. Most of the fractures of the lower end of the radius are the result of either industrial injuries or osteoporosis seen with advancing age. They comprise 8.8 per cent. of all fractures and occur most commonly between the ages of thirty and fifty. Eighty per cent. occur in men.

The author classifies the fractures of the lower end of the radius as follows:

1. Juxta-articular or peri-articular fractures:
   a. Classical type (Pouteau-Colles),
   b. Fractures in children (epiphysiolysis),
   c. Rare type (inverted).
2. Articular fractures:
   a. Partial,
   b. Complete.
3. Fractures or other lesions associated with fractures of the distal third of the radius:
   a. Ligamentous injuries,
   b. Separation of the ulnar styloid,
   c. Fracture of the lower end of the ulna,
   d. Luxation of the lower radio-ulnar joint,
   e. Fractures and dislocations of the carpal bones,
   f. Lesions of the nerves.

The various theories concerning the mechanism causing the fracture are reviewed. Fractures of the lower end of the radius usually result from the hyperextension of the wrist; in children, because of the attachment of the ligaments, this injury produces epiphyseal separation. There may be indirect force transmitted from the palm of the hand, there may be a ligamentous pull, or there may be a direct crushing injury. Much depends upon the position of the hand during the fall. The author believes that the direct transmission of force with inward deviation of the wrist explains complete fractures or crush injuries.

The author divides treatment into that for fractures without displacement or penetration and that for fractures with displacement or penetration or both. In the first type, he advises the use of a padded circular plaster cast from the upper third of the forearm to the heads of the metacarpals for three or four weeks. In the second type, with displacement or impaction, one should obtain as exact a reduction as possible under local anaesthesia. He recommends the use of a special apparatus, described by Ayrola in 1939 in *El Dia Medico*, with clamp traction upon the thumb and with slight traction upon the other fingers. Traction with fifteen to thirty kilograms is continued until the fracture can be reduced by gentle manipulation. Restoration of the normal length of the radius is essential. To achieve this, the wrist is held in maximum ulnar deviation, and a padded circular plaster cast is applied before traction is loosened. The plaster should be well molded about the base of the thumb and should extend from the elbow to the heads of the metacarpals, leaving the thumb free. The reduction should be checked by roentgenogram. The limb is usually kept elevated for the first twenty-four hours, and the arm should be examined the following day. If there is oedema or impairment of the circulation, a rare occurrence with this technique, the plaster is split along the ulnar side.

In fractures fairly high on the radial shaft, the plaster may extend to the upper third of the arm. The treatment will vary with the type of fracture. In inverted fractures, the wrist may have to be put in slight dorsiflexion. With fractures of the ulna or ulnar styloid, ulnar deviation may not be required. From the beginning, all joints should be actively exercised except those which must be immobilized. After the plaster has been removed, in from four to five weeks, heat, exercise, and occupational therapy should be continued until full motion and strength have been regained.

The complications and sequelae mentioned by the author are adhesions following tendonitis, vernous stasis, errors of consolidation, laxity of the ligaments about the wrist, rigidity and ankylosis of the joints, and lesions of the median and ulnar nerves. Late sequelae including fraying of the long extensor of the thumb, traumatic osteoporosis, and Sudek's atrophy are also discussed.

The author deplores the statistics which give early rather than late results in these fractures. He reviews the histories of fifty-nine cases followed for a prolonged period. Surgery is mentioned briefly but is not discussed.

A chapter on the laws of traumatic injuries as they concern these fractures is added. There are a number of excellent photographs, and a comprehensive bibliography is given.

POST-GRADUATE LECTURES ON ORTHOPAEDIC DIAGNOSIS AND INDICATIONS. Vol. I. Arthur Steindler, M.D., F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1950. $7.50.

For many years the numerous students of this renowned teacher and clinician have been urging him to

make his lectures available in book form. The present volume is Volume I in this series, and it sets a high standard for the other two volumes now being written.

Volume I is divided into two sections:

Section A: Propedeutics in Orthopedic Diagnosis,

Section B: Congenital Deformities and Disabilities.

The term propedeutics in Section A means preliminary instruction. The author skillfully takes the student of orthopaedic surgery through the fundamentals of this field to prepare him for the day when he must analyze and manage clinical situations.

As has been his custom through more than thirty years of clinical teaching, Dr. Steindler vigorously emphasizes that the student is not ready to learn details of operative technique until he has learned diagnosis and indications.

The titles of the lectures in Section A are:

I. Symmetry and Asymmetry of the Body.
II. Contractures.
III. The Interpretation of Pain in Orthopedic Surgery.
IV. The Pathology of the Gait.

There is much on kinesiology in this first section; in this complex field Steindler has no peers. The student will also acquire from this book an orientation in that difficult borderline area which lies between normal and pathological behavior of the locomotor system.

In Section B, material is presented on a wide variety of congenital deformities of the skeletal system. This is not merely a description of these deformities, but includes a historical review, a detailed evaluation, and an analysis of their pathomechanics.

The following lectures make up Section B.

I. Congenital Deformities of the Locomotor System.
II. Congenital Deformities Due to Disturbance of Bone Growth: the Chondrodystrophies.
III. Congenital Deformities of the Spine and Thorax.
IV. Congenital Talipes.
V. Congenital Defects and Malformations of the Long Bones of the Lower Extremities.
VI. Congenital Dislocation of the Hip.
VII. Congenital Deformities of the Upper Extremity.

Whereas volumes on operative technique are soon out of date, this treatise on diagnosis and indications deals with fundamentals which change but little with the years. This fine book will undoubtedly have a long and useful life, and should be within easy reach of all whose work is concerned with the locomotor system.

Most of the illustrations have been well reproduced, and the publisher deserves to be commended upon the fine physical qualities of this book.

SURGERY, ORTHODOX AND HETERODOX. Sir William Heneage Ogilvie, K.B.E., D.M., M.Ch., F.R.C.S. Oxford, England, Blackwell Scientific Publication Ltd.; Springfield, Illinois, Charles C. Thomas, 1950. $4.00.

This book is made up of twenty-one reprints from medical journals which the author has pruned and rejuvenated. The articles themselves deal not only with the philosophy of the surgeon's art, but also represent a collection of clinical observations and principles. The author's point of view is both thoughtful and thought-provoking. His observations arise from a vast experience gained from wide travel and from an extensive acquaintance with fellow surgeons in Britain and in America. Such articles as those dealing with orthodoxy and heterodoxy, religio chirurgi, and a surgeon's life show deep insight into the philosophical principles of the profession. The provocative article on "The American Surgeon" gives us a fair commentary on our American ways, and helps us to "see ourselves as others see us". Three chapters of particular interest are "Misleading, Leading Symptoms", "The Place of Medical Societies in the Doctor's Life", and "Social Medicine". The latter article, although brief, contains several good phrases. "Organization must come in all states and in all sciences. . . . Organization is no substitute for genius. No amount of bureaucracy could have discovered penicillin." "Bureaucracy, by its very nature, tends to go beyond its mandate. Its job is to regulate, and it is thus apt to love regulation for its own sake. . . ."

All in all, this book provides a wealth of mature and well expressed opinions which the author has plainly drawn from a busy lifetime spent in the practice of surgery.

HISTOLOGY. Arthur Worth Ham, M.D. Philadelphia, J. B. Lippincott Company, 1950. $10.00.

It is seldom that one picks up a textbook and discovers that within its scope it completely fulfills all his needs. Such a book is Professor Ham's *Histology*. It is easy for students to understand; Professor Ham has an extraordinary gift of exposition, both in word-picture painting and schematic line drawing. No subject seems too difficult or too complex for his facile pen. For example, the developmental and growth sequences of cartilage and bone are presented with a clarity that brings a far deeper insight and understanding than many students would believe they could possibly have attained. The orthopaedic surgeon who masters the chapters

which concern him—and this means most of the book—will find himself amply rewarded, not only in his grasp of first principles as they apply to his specialty, but in his ability to interpret and understand the new developments in medicine and in surgery in general—in a word to keep abreast of the times.

While naturally the emphasis is on structure, the reader will find that he is maintaining at all times a keen interest in chemical, physical-chemical, and enzymological processes which are going on hand-in-hand with the morphological changes he observes.

From the publishing standpoint, the workmanship is good. There are some 756 pages with 445 figure numbers in the reproduction of which the standard is consistently high.

As a medical-school and biological-science text for general courses in histology, and for background for the medical-research worker and for the clinician, this book seems ideal. It seems hardly too enthusiastic to suggest that it may well be destined to become a classic.

MANUAL OF RHEUMATIC DISEASES. W. Paul Holbrook, M.D., and Donald F. Hill, M.D., with the assistance of Charles A. L. Stephens, Jr., M.D. Chicago, The Year Book Publishers, Inc., 1950. $4.50.

In this little manual the authors have prepared for the general practitioner a guide to the understanding and treatment of various types of arthritis and rheumatic disease, as well as of the collagen diseases.

In brief and simple form, the authors have stated the accepted facts about these diseases and have given precautions for the prevention of fixed deformities. Well chosen illustrations demonstrate the acute phases of the diseases and resultant deformities.

One chapter is devoted to cortisone and ACTH, and their possible places in the future treatment of these conditions. The chapter on "Prevention and Correction of Deformities" should be of special value to the physician who first sees patients suffering from these diseases. As a concise manual for this group, the book fulfills its purpose.

PHYSIOLOGY AND ANATOMY. Ed. 6. Esther M. Greisheimer, B.S., M.A., Ph.D., M.D. Philadelphia, J. B. Lippincott Company, 1950. $4.00.

This is the sixth edition of an excellent introductory course in physiology and anatomy which is written primarily for student nurses, from the author's experience in teaching.

The sixth edition presents in several places an extensive rewriting or revision. Much new material has been added; much material has been brought up to date; and much, in the author's own words, has "been treated more adequately than in previous editions". The principal change to be noted is the complete revision of the chapters on the physiology of the muscular system and on the blood. Also, the chapters on the circulatory system and vitamins have been brought up to date.

This text, attractively bound and illustrated, should be a valuable addition to the student's reference library. It is a compact and convenient volume, and the fundamentals of anatomy and physiology are so lucidly presented that the student gains a new appreciation of the relationship between human structures and their functions.

EVALUATION OF INDUSTRIAL DISABILITY. Prepared by the Committee for Standardization of Joint Measurements in Industrial Injury Cases of the California Medical Association and Industrial Accident Commission, State of California. New York, Oxford University Press, 1950. $4.00.

Since the evaluation of industrial disability has been accomplished in the past by several conflicting methods, the results have been confusion, delay, and inconvenience for all persons concerned. This manual is an attempt by a group of California medical men and other interested persons to introduce in their state a degree of uniformity for joint measurement in industrial accident cases. It will also enable medical examiners to give a clear word picture of the extent of disability, in terms which laymen as well as medical men will be able to employ without risk of misunderstanding.

The first section of the manual is devoted to general instructions on the fundamentals of reporting joint motion, the evaluation of subjective complaints, and the evaluation of abnormalities and deformities in so far as they concern the report; it continues with detailed instructions, fully illustrated, for joint disability measurement; and it concludes with a brief consideration of certain special disabilities — those of the eye, ear, head, and mind.

Well bound and profusely illustrated, this book should enable medical examiners to introduce into the writing of their reports a considerable degree of uniformity.

A SYNOPSIS OF SURGICAL ANATOMY. Ed. 7. Alexander Lee McGregor, M.Ch. (Edin.), F.R.C.S. (Eng.). Bristol, England, John Wright and Sons Ltd.; Baltimore, The Williams and Wilkins Company, 1950.

Those acquainted with the earlier editions of this rightfully popular and practical collection of essays on surgical anatomy will find that the great bulk of material and illustrations in this new edition is familiar.

New sections have been added to two of the essays,—a discussion of transthoracic approaches to the essay on "The Anatomy of Surgical Approach" and a presentation of operations on the blood vessels to the essay on "The Anatomy of Surgical Procedures". While these are the most complete revisions in the book, changes have been incorporated in several other sections of the work; the section dealing with the sympathetic nervous system has some new material. The work as a whole boasts some seventy new illustrations.